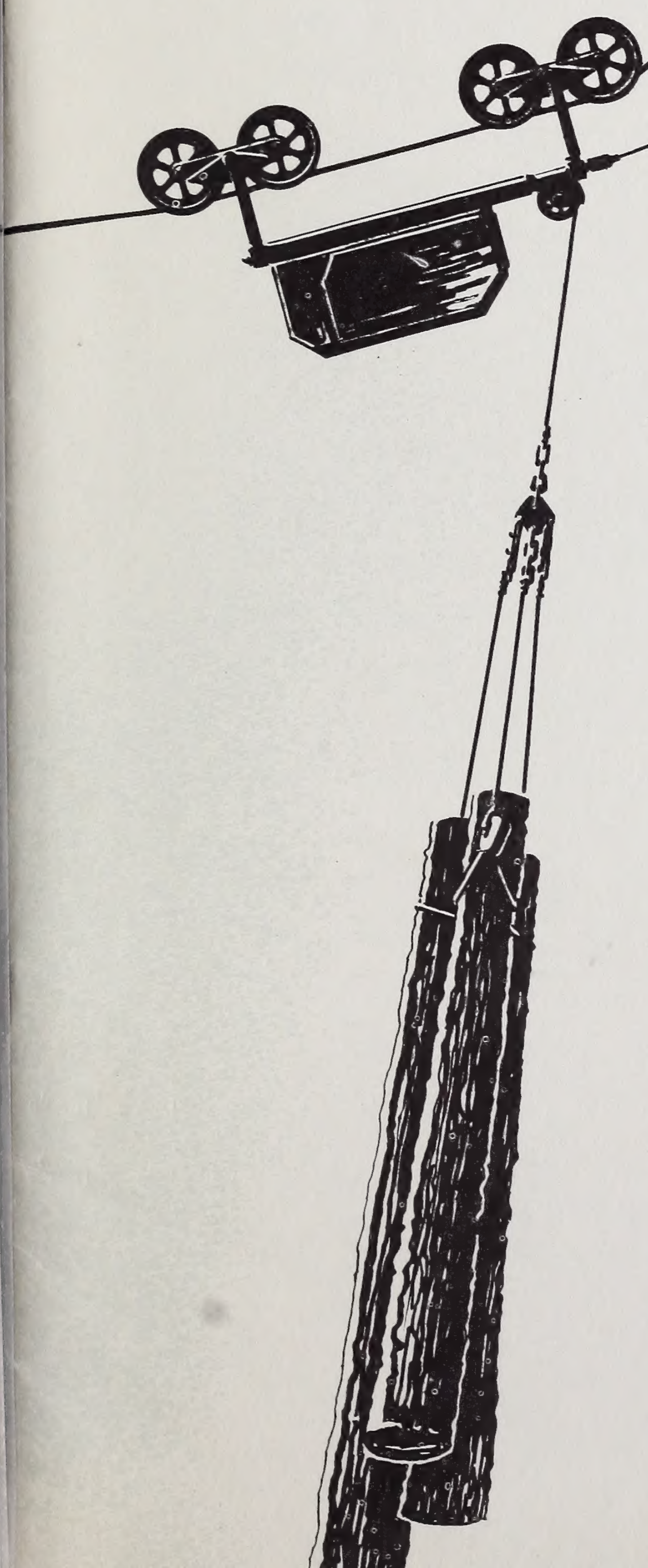
# Economics and Design of a radio-controlled SKYLINE YARDING SYSTEM



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# Introduction

Soil and watershed values are of critical concern to forest-land managers in many parts of the Pacific Northwest where steep slopes and potentially unstable soils may preclude logging by conventional methods. Ruth[1] estimated from 1.5 to 3.8 million acres of commercial forest land on the National Forests of Oregon and Washington that should be managed with special effort to minimize soil disturbance. Similar problem areas are found on other ownerships. In an effort to log these economically and carefully, such recent developments as gravity-operated skyline systems, helicopters, and balloons have been tried. In each instance, the main purpose has been to reduce the amount of road construction needed and to minimize soil disturbance during yarding. This study was undertaken to determine the economy of a skyline logging system being used on a problem area in the coastal forests of Oregon.

The chief feature of skyline yarding systems is that logs are yarded laterally to a suspended cable and then transported longitudinally along the cable to a landing. Typically, the skyline is located on a slope, with the logs lowered down the skyline by gravity.[2] Total length of the skyline may be as much as 1 mile. Thus, in comparison with conventional high-lead yarding where yarding distances are generally under 1,000 feet, skyline yarding not only minimizes soil disturbance but, even more important, eliminates much secondary and spur-road construction.

This study of costs has revealed the especial need for advance engineering and planning and detailed estimating to reduce or hold down the high cost of rigging, moving time, and nonproductive time associated with skyline logging systems.

Therefore, this report makes an analysis of engineering and cost information that should be helpful to timber sale administrators and logging managers in achieving efficient operation and favorable results.

[1] Ruth, Robert H. It's time to look at yarding problems on steep slopes. U. S. Forest Serv., Pac. NW. Forest & Range Expt. Sta. Res. Note 185, 4 pp., illus. 1960.

[2] Uphill systems are also possible, but will not be covered in this report.

# The Study Area

This study was conducted in the undeveloped Fall Creek drainage of the Cascade Head Experimental Forest near Otis, Oregon. The spruce and hemlock trees were predominantly 115 years but occasionally 200 or more years old. The broken terrain of the area is typical of the coastal ranges of western Oregon. Elevation varies from 160 to 1,700 feet above sea level. Timber volumes ranged from 50,000 to 90,000 board feet per acre. Yarding of the study area was done from January 1960 to February 1964.

An experimental sale, consisting of approximately 20 million board feet, was laid out in five cutting units. A main haul road was constructed up the drainage to the bottom of each unit. Also, short administrative roads or "tote roads" were constructed to the top of each unit. These tote roads were negotiable by track vehicle only and were used for moving the snubbing machine, or yarder, to the top of each unit and providing access for men and material. This was in contrast to the more typical high-lead logging system with hauling roads at the top of the unit.

Length of the skyline road (cableway) varied from 2,000 to 4,400 feet. The number of intermediate supports on any one skyline road varied from none to two.

Unit 28 was logged first, with four single-span skyline roads approximately 2,300 feet long. Unit 31 was logged with three multispan skyline roads. One road in this unit was yarded uphill to test the equipment for uphill use. The production rate uphill was not significantly different from gravity operation.

The back slope of unit 32 was yarded by high lead using a separate yarder, and the logs were then swung to the landing by the radio-controlled carriage on the skyline (fig. 1). Unit 37A was yarded with three 2,100-foot single-span skyline roads, with the snubbing machine located near the landing. The snubbing line was rigged similarly to the haulback line on a high lead. Operation with the snubbing machine (yarder) located at the landing proved to be quite satisfactory. Unit 37B was the most difficult unit of the five to yard. Broken terrain and lack of suitable intermediate support trees required the use of a cross or intermediate support skyline. This method of rigging will be discussed later in this paper.

A detailed time study of operations was made on cutting unit 32. Cutting-unit design and field engineering procedures were developed during layout of units 32 and 37B.

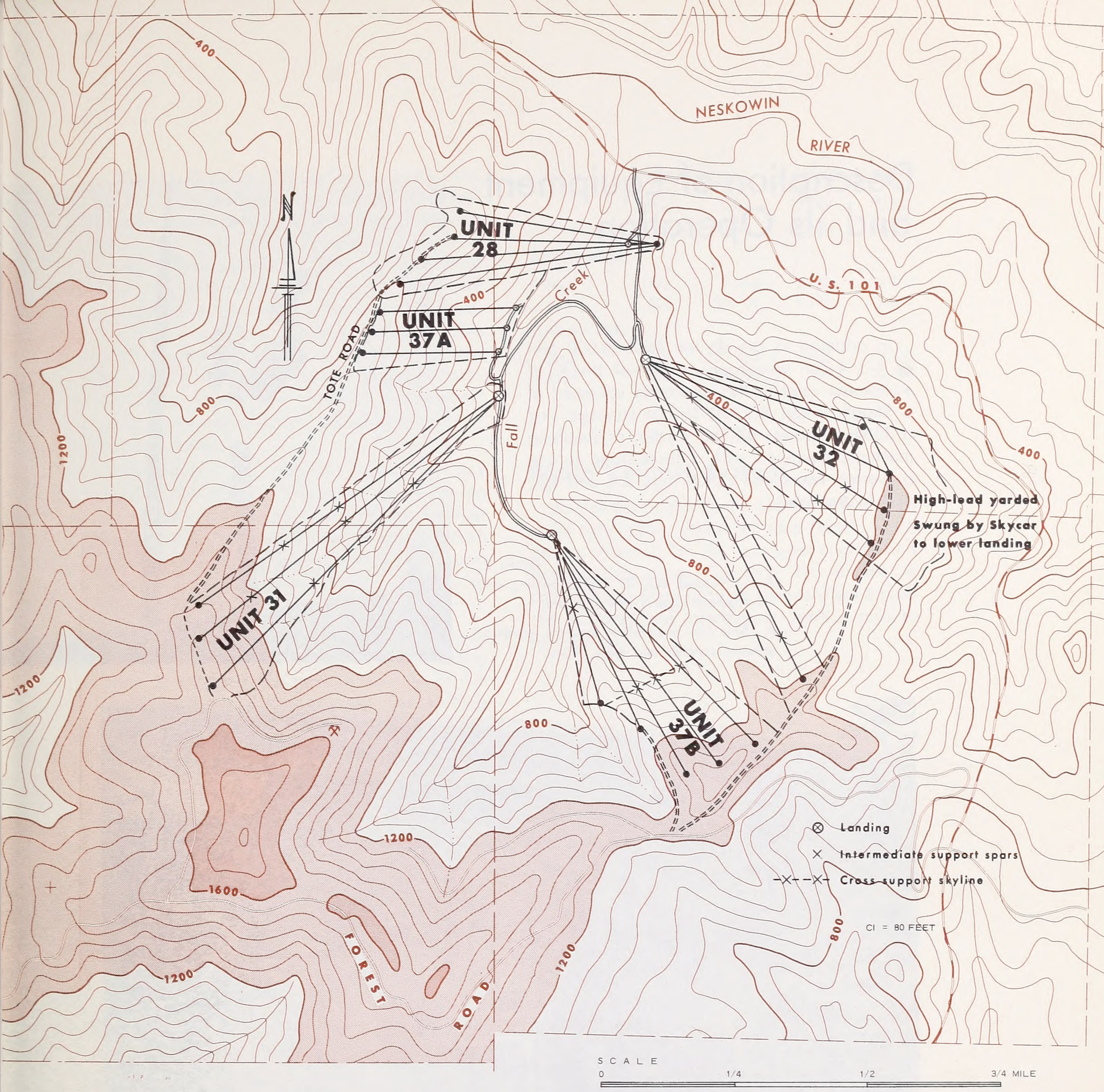



Figure 1.—Topographic map of experimental sale area showing skyline cutting units and road network for the Fall Creek drainage of the Cascade Head Experimental Forest.

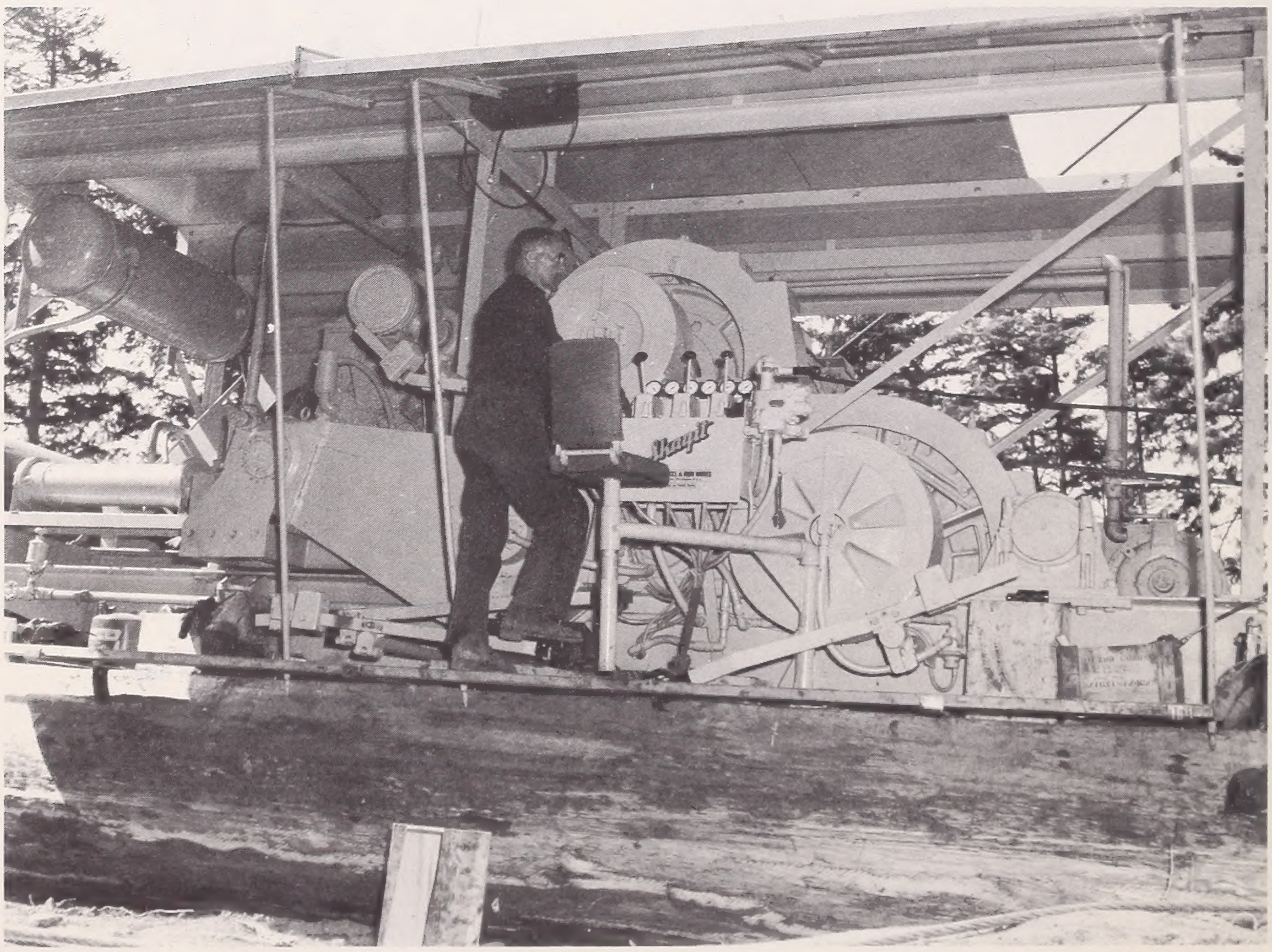
# Description of Equipment and its Operation

In addition to the skyline itself (5,000 feet of 1-3/4-inch wire rope), the chief pieces of equipment used in this operation consisted of a Skagit Model RCC-20 Skycar carriage and a 335-horsepower BX-185 yarder, or snubbing machine, equipped with a three-stage torque converter, two-speed clutch (figs. 2A and 2B), and hydrotarder.

Figure 2

A. A loaded RCC-20 Skycar passing an intermediate support tree and jack.

B. Side view of snubbing machine (yarder) showing controls and main drums.



The Skagit Model RCC-20 Skycar, which rides on the main skyline, incorporates a 95-horsepower GMC Model 4-53 diesel engine driving through a twin disc, three-stage, dynamic breaking torque converter. Power is transmitted from the torque converter to the drum set through a propeller shaft. The reversible, load-line drum is engaged by air-operated multiple clutches. The RCC-20 Skycar is suspended from the skyline by an open-side carriage; e.g., the Skycar is permitted to travel past support jacks, which suspend the main skyline at intermediate points.

The Skycar suspension system has four sheaves, 36 inches in diameter, which ride on the main skyline. Suspension from the four sheaves is by a patented swivel system which allows the Skycar to remain in a relatively perpendicular position while yarding laterally to the skyline.

The diesel engine runs at idle speed until accelerated by radio impulse, when the skidding drum is engaged for paying out line or for skidding the turn to the carriage. The skidding drum has a capacity of 400 feet of 7/8-inch-diameter wire rope, which permits lateral skidding of approximately 300 feet. The no-load speed for paying out slack is 400 feet per minute; for paying in, it is 319 feet per minute, with a stall pull of 40,000 pounds. Line speeds and pulls are based on average drum conditions. The designed weight-carrying capacity of the Skycar is 40,000 pounds. Gross weight of the RCC-20, including wire rope, fuel, and water, is 8,140 pounds.[3]

## Snubbing Machine

The snubbing machine has three drums. One holds 4,400 feet of 1-inch snubbing line; another, 5,700 feet of 3/4-inch haulback line (used for rigging intermediate support spars and for tensioning the skyline); and the third, 5,000 feet of 7/16-inch straw line. The snubbing machine is equipped with a hydrotarder which is used to brake the speed of the loaded carriage down the skyline. Line speeds and pulls, based on average drum conditions, are as follows:

[3] Data from Skagit Corporation.

| | MAIN DRUM | | HAULBACK DRUM | |
|---|---|---|---|---|
| | SPEED (ft./min.) | PULL (lbs.) | SPEED (ft./min.) | PULL (lbs.) |
| HIGH RANGE: | | | | |
| High | 775 | 7,150 | 2,450 | 2,260 |
| Low | 352 | 15,700 | 1,130 | 5,000 |
| LOW RANGE: | | | | |
| High | 202 | 29,400 | 635 | 9,350 |
| Low | 92 | 64,000 | 290 | 20,400 |

## Radio Control System

An operator controls the Skycar with a small radio transmitter, called a Talkie-Tooter, which has a channel for the carriage engine and skidding-line drum (fig. 3). The engine is controlled at three possible speeds when it pulls the skidding line laterally or skids a turn to the skyline.

Figure 3.—Talkie-Tooter transmitter is attached to the belt of the operator (shown near the left elbow of the workman in the center of the photo).

The Talkie-Tooter has a control selector on the end of the handle with four signal positions: up, down, stop, and whistle. Two features are built into the Talkie-Tooter which help insure personnel safety. The selector must be moved through "stop" each time the up or down cycle is used. A second safety feature is a two-position, squeeze handle, signal switch. The switch has both a warmup and a signal position to complete a signal cycle. A partial squeeze of the handle activates only the warmup switch. This feature helps insure that a signal will not be transmitted accidentally by bumping the handle. When the carriage is at rest and activation of the load-line drum is not desired, the selector switch is kept at "stop." The Talkie-Tooter also transmits voice signals to receivers on the Skycar and yarder.

Three Talkie-Tooter transmitters are used on a radio-controlled skyline logging system. The unhooker (chaser) at the landing and the rigging slinger in charge of the choker setters each has a transmitter. A spare transmitter is kept at the snubbing machine to be used in operating the carriage when supplies are sent up the skyline to the snubbing machine.

The following audible signals were used:

| | | |
|---|---|---|
| — — | Ahead on snubber line | Slow (power) |
| — — — | Ahead on snubber line | Fast (power) |
| Voice signal | Ahead on snubber line | Slow (gravity) |
| — — — — | Ahead on snubber line | Fast (gravity) |
| — | Stop any moving line | |
| -- -- -- | Lower skyline | |
| -- -- -- - | Raise skyline | |

Each turn of logs involves the following sequence in use of the Talkie-Tooter. As the empty carriage approaches the area of loading, the operator moves the selector from "stop" to "whistle," signaling the snubbing machine operator to stop the carriage. The selector is then moved to "down" and the skidding line is lowered and pulled laterally to the turn of logs. When the skidding line is near the logs, with the selector at "stop," the signal switch is pressed, stopping the yarding drum in the carriage. The selector is moved to "up" when the turn is hooked and the crew is in the clear. The carriage drum is activated, skidding the logs to the skyline. The selector is then moved to "stop" and the skidding drum is stopped when the turn is under the carriage. The selector switch is then moved to "whistle," and a whistle signal is blown to indicate that the loaded carriage is to be lowered along the skyline to the landing. The operator then moves the selector to "stop" until the carriage returns.

When the carriage nears the landing, the chaser moves the selector of his transmitter from "stop" to "down" and lowers the turn while the carriage is moving. Markings on the snubber line indicate to the snubbing-machine operator when the carriage has reached the landing.

After activating the down cycle, the chaser moves the selector to "stop" and stops the skidding drum when the turn is on the landing. After chokers are unhooked, he moves the selector to "up," and the skidding line and chokers are pulled to the carriage. As the butt-hook and chokers near the carriage, the drum is stopped and the signal made to return the carriage to the working area. The chaser then switches the selector to "stop" and waits for the next turn.

## The Operation in Brief

A skyline yarding system can be described as a system that can yard logs laterally to a suspended cable as well as transport these logs longitudinally along the cable to a landing.

A complete cycle of operation for a skyline-crane yarding system consists of six phases. In this paper, they will be referred to as $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, and $T_6$.

Phase $T_1$ is the time required to move the carriage from the landing along the skyline to the point of loading.

Phase $T_2$ is the time required to pull the skidding line laterally from the carriage.

Phase $T_3$ is the time required to hook a turn of three logs to the skidding line.

Phase $T_4$ is the time required to skid a turn of logs laterally to the skyline.

Phase $T_5$ is the time required to move the loaded carriage along the skyline to the landing.

Phase $T_6$ is the time required to unhook a turn of logs at the landing.

Figure 4 shows a plan view of a cycle of operation for a skyline yarding system.

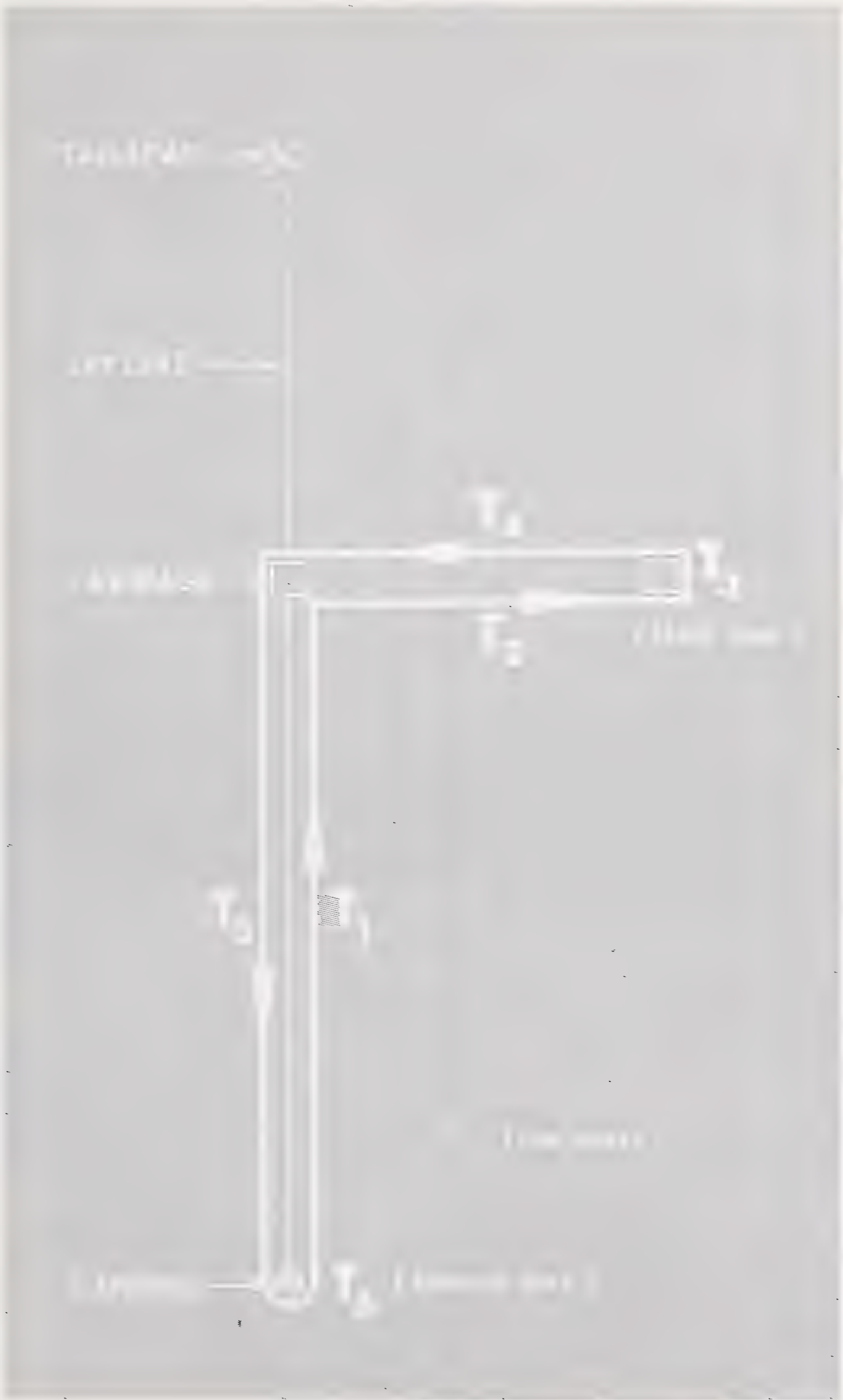


Figure 4.—Plan view of a skyline yarding cycle.

# Layout and Design

This study involved much first-hand observation of cutting-unit design and layout. Also, other skyline systems were visited in Oregon, Washington, and British Columbia. In this paper, cutting-unit shapes and skyline layout are specified for several topographic conditions, special rigging situations are identified, and the necessary field and office work is described for a cutting unit and for an extensive drainage area.

## Skyline Cutting-Unit Design

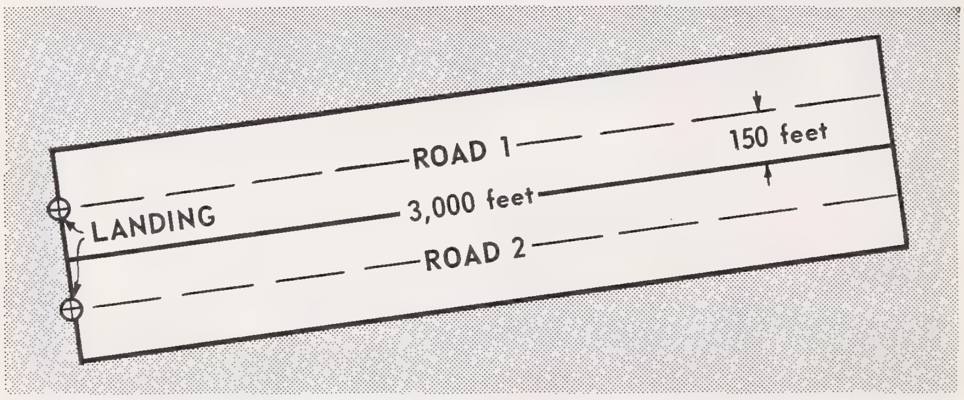
Skyline cutting units may be rectangular in design, with parallel skyline roads, or fan shaped, with skyline roads radiating from a single point (fig. 5). The rectangular shape is more desirable. For example, compare the two units illustrated:

| | Fan-shaped road | Rectangular road |
|---|---|---|
| External distance | 3,000 feet | 3,000 feet |
| Average yarding distance | 3,000 X 0.5 = 1,500 feet | 3,000 X 0.667[1] = 2,001 feet |
| Area served by each skyline road | 20.66 acres | 12.40 acres[2] |

[1] Average yarding distance factor.

[2] Based on the area of a triangle of 3,000 feet long with a base of 360 feet.

Note that the same length of skyline serves 8.26 more acres in the rectangular shape than in the fan shape, with a shorter average yarding distance. However, terrain and the costs of moving and rigging at the landing may make the fan shape preferable.



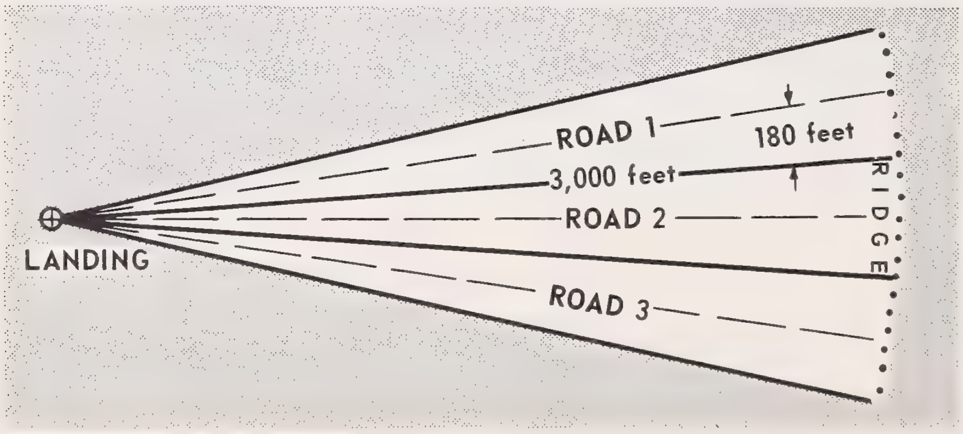
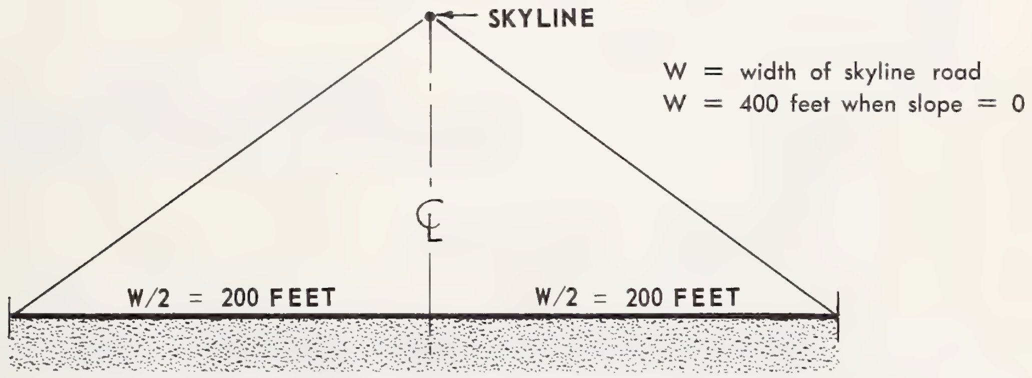




Figure 5.—Rectangular cutting unit, with two parallel skyline roads, and fan-shaped cutting unit, with three skyline roads radiating from one landing.

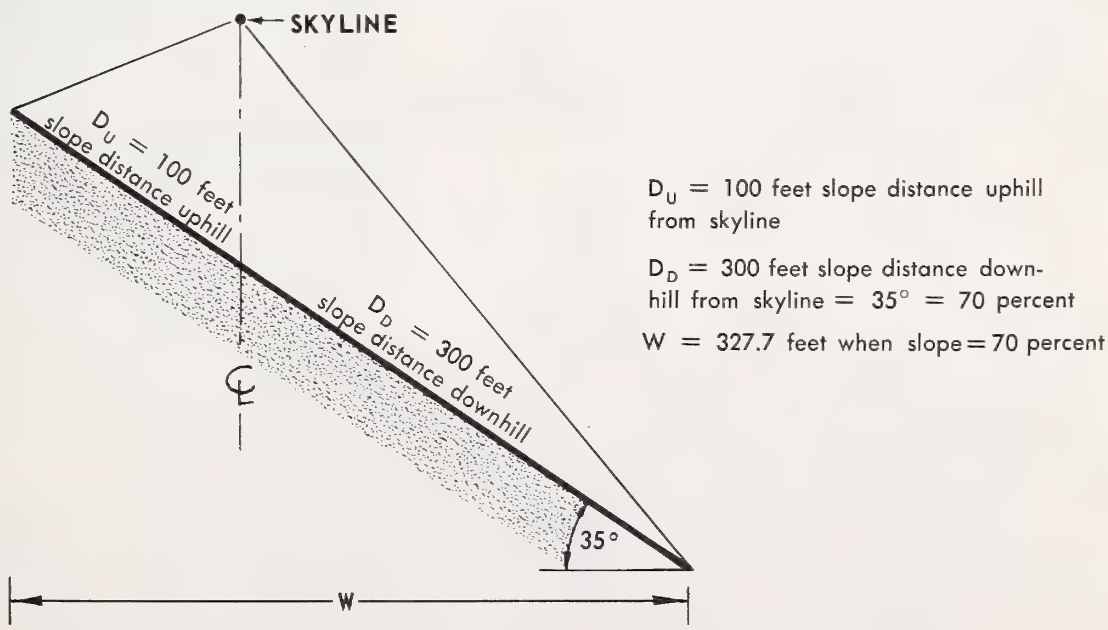
## Effect of Side Slope Under the Skyline

Skylines are frequently set up with the skyline following the contour; thus, the ground slope laterally under the skyline may vary from 0 to 100 percent or more. A steep side slope sharply restricts the distance the skidding line can be pulled uphill, and, although the line can be pulled farther downhill, the total width of the skyline road is markedly less. This, in effect, reduces the area served by each skyline road.

For example, in this study the rigging crew was able to pull the skidding line only 100 feet slope-distance uphill from the skyline, but could pull it 300 feet downhill on a 70-percent side slope. If a skyline road is 4,500 feet long with no side slope, it would cover 41.32 acres; a strip with 70-percent side slope would cover 33.85 acres, a difference of 7.47 acres (fig. 6).

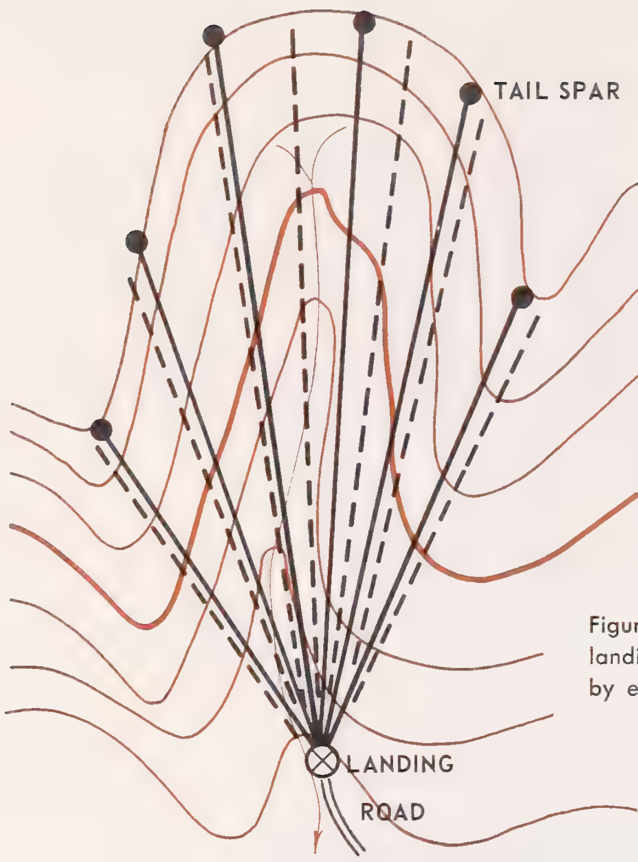



Cross section of a skyline with a lateral slope under the skyline of 0 percent.




Cross section of skyline with a lateral slope of 70 percent.

Figure 6.—Example of effect of side slope under the skyline.

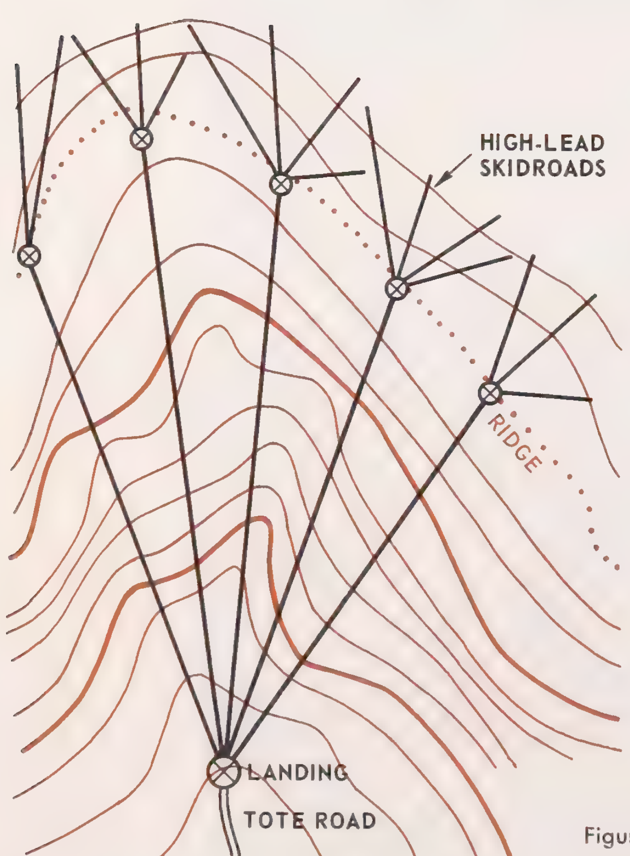



## Fan-Shaped Unit

A fan-shaped unit is generally used when a cutting unit is laid out in a drainage head (fig. 7). A single spar is used at the landing and the skyline roads radiate to tail spars spaced along the outer edge of the unit. Note that each skyline is not in the center of the road or area to be logged, because the weight of the butt-hook and chokers cannot be pulled by hand as far uphill as on the level or downhill.

Fan-shaped units in a drainage head may be particularly troublesome in this respect, due to the amount of sloping ground frequently encountered.

Figure 7.—A fan-shaped unit with skyline roads radiating from a landing. Solid lines are skylines and dashed lines indicate area served by each skyline. Contour lines are also shown.




## Fan-Shaped Unit with High-Lead Yarding from the Reverse Slope

A combination of high-lead yarding with a skyline crane swing to a landing may often be practical (fig. 8). This may require a combination yarder-snubbing machine at the top of the unit. Such a machine could be used to high lead and cold deck at the tail spar as well as serve as a skyline crane snubbing machine. In cases where large volumes are available, it may be practical to move a separate high-lead yarder to the tail tree and use a hot-deck swing operation. Should the capacity of the skyline crane be greater than the high-lead machine, the skyline crane can work as a yarding unit on the skyline road until a sufficient cold deck is available for a maximum capacity swing. Alternating skyline yarding and swinging will maximize the production of the logging system.

Figure 8.—Fan-shaped skyline unit with high-lead yarding from the reverse slope.

## Rectangular Unit

Rectangular units are usually laid out on slopes having a flat face and a gradient of 30 percent or greater (fig. 9). The rigging consists of a head spar, a tail spar, intermediate supports as required, and a landing.

The unit is laid out perpendicularly to the contour of the slope, giving a side slope across the contour or nearly so.

Rectangular cutting units, as shown in figure 10, represent the most desirable design that can be incorporated into a skyline logging plan. Average lateral and longitudinal distances are one-half the external distances, thereby providing the maximum area to be logged by each skyline road.

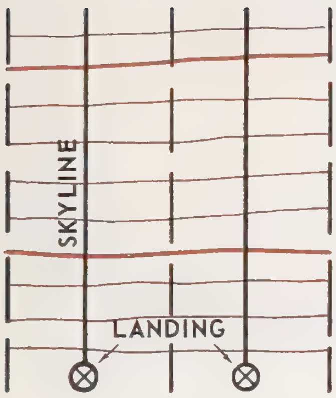
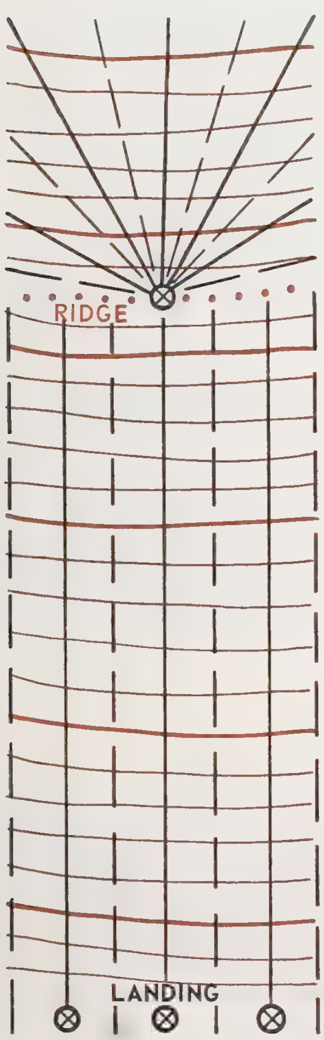



Figure 9
A rectangular cutting-unit design on a long, continuous slope face.

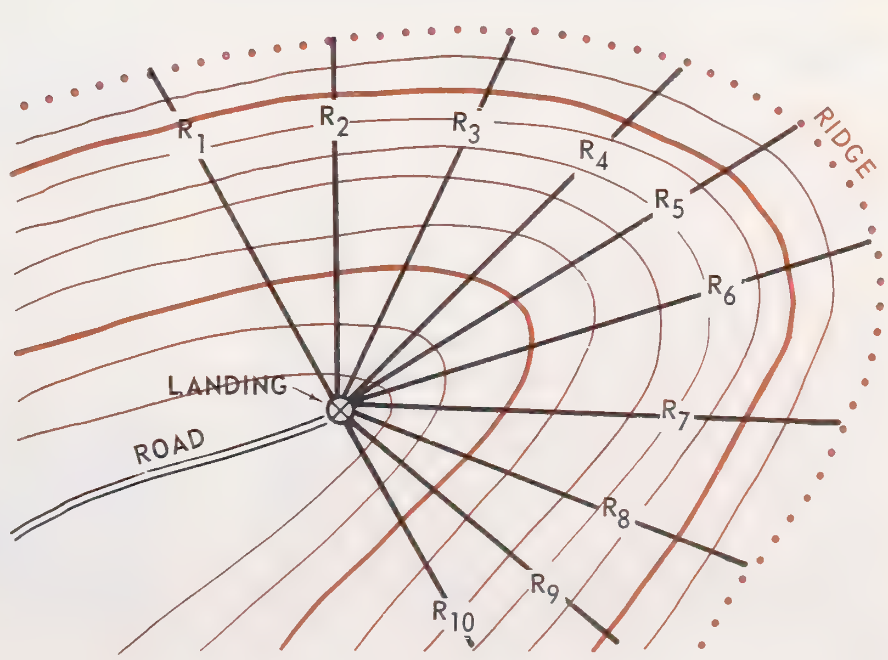
Figure 10
A rectangular unit with a high-lead swing from a reverse slope.




## Half-Circle Skyline Unit

Large bowl-shaped drainage heads, or valley heads, present topographic features adaptable to a half-circle design (fig. 11). Large units result from this type of design, and alternate cutting of the skyline roads would encourage more natural regeneration.

Figure 11.—Topographic situation suited for half-circle cutting-unit design.



## Dragging

Dragging can occur if there is a large amount of deflection in the skyline. This should be avoided by careful preparation of skyline profiles and by proper design of cutting units (fig. 12). Dragging increases cycle time and puts a severe stress on the equipment when the logs swing free after a period of dragging.

Logs, hanging in a perpendicular position under the descending carriage, often strike the ground ahead of the carriage. When this occurs, there may be damage if the carriage strikes the elevated ends of the logs as it passes over the dragging point.

Figure 12.—Turn of logs dragging during downhill swing. A number of logs striking the same spot can cause undesirable gouging of the soil.

## Slope Condition Profiles

Three basic types of ground profile that may be encountered in the design of a skyline crane cutting unit are concave, convex, and constant.

CONCAVE PROFILES.—Concave profiles can often accommodate a free span (fig. 13). However, figure 14 shows a concave slope condition where intermediate supports are required. Such conditions may present a problem of deflection when one subspan is loaded. When the loaded carriage is in one subspan, deflection is drawn from the remaining three subspans, possibly causing the logs to drag if the ground profile will not accommodate the deflection in the loaded span. Such slope conditions should be avoided when gravity-operated skyline logging systems are being designed.


Figure 13
Single-span skyline on a concave profile that will allow passage of a loaded carriage clear of the ground.

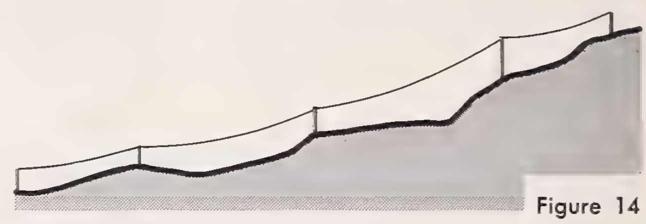


Figure 14
Concave profile that requires the use of support trees.

CONCAVE PROFILE CROSSING RIDGE LINE.—A depression in a profile, as in subspan 2 of figure 15, caused by crossing of a ridge line, should be avoided in cutting-unit design because a large sag in the snubbing line develops in subspan 2, making the speed of the carriage at the top of subspan 1 difficult to control. In this case, the velocity of the carriage increases rapidly after passing the support. Complete control of the carriage is not regained until the slack is pulled from the snubbing line in subspan 2. Excessive strain results on the rigging, carriage, snubbing line, skyline, and snubbing machine. The added height above ground of the skyline in subspan 2 increases the time to perform the lateral-out ($T_2$) and lateral-in ($T_4$) phases of the logging cycle. Cutting units should be laid out so as to avoid such conditions.

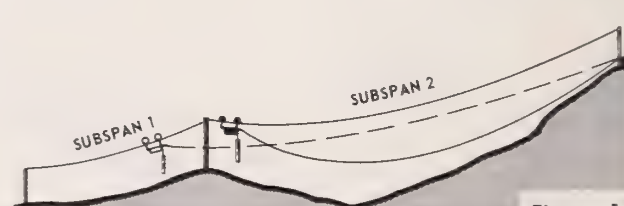



Figure 15
Skyline profile showing carriage crossing a ridge line in the unit.

CONVEX PROFILE.—A convex profile requires the use of intermediate supports (fig. 16), but locating these supports and tensioning of the skyline are less complex problems than found with other slopes. In this case, tensioning the skyline exerts a downward force on the skyline jack instead of lifting it, as might occur in a concave slope condition. Proper spacing of the supports and correct tensioning of the skyline are essential to reduce the possibility of dragging in the various subspans.

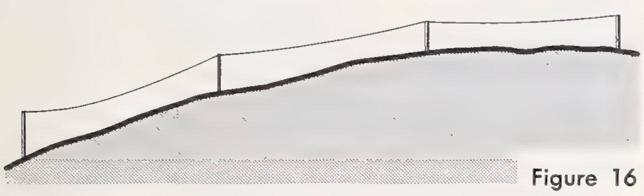


Figure 16

Convex profile with intermediate supports.

CONSTANT PROFILE.—A constant profile presents a problem similar to that of a concave profile (fig. 17). The possibility exists that one of the supports will be shorter than the others (fig. 18). Under this condition, when the loaded carriage is in subspan 1, deflection is drawn from subspans 2 and 3, raising the skyline above the short intermediate support and putting a severe stress on the skyline jack, possibly inverting it.

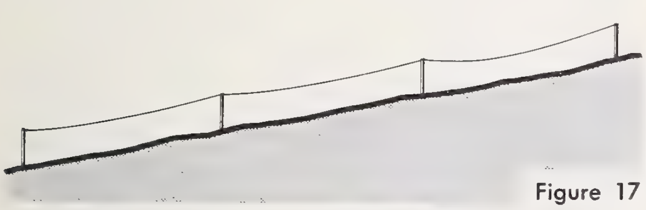


Figure 17

Constant profile with support trees.

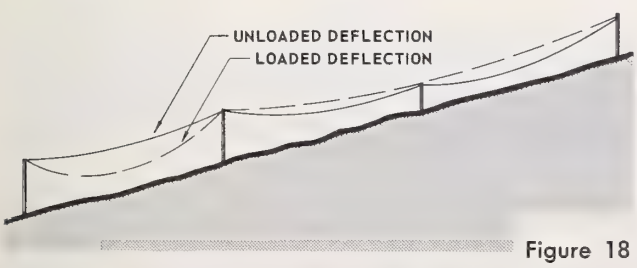



Figure 18

A constant profile with one short intermediate support spar.

## Intermediate Support Spars

When terrain features are such that a single-span skyline cannot be used, the skyline must be held clear of the ground by intermediate supports to allow the carriage and load to pass without contacting the ground. Intermediate support spars fall into three classes: standing, leaned, and raised.

Standing intermediate support spars are trees directly alined with the skyline and can be rigged in place. When rigged, this type of support resembles the conventional high-lead spar tree in appearance. The skyline jack is held in position by a reinforced guy line.

Leaned intermediate supports are trees which are cut on the stump and leaned to facilitate alinement with the skyline. The base of the tree is tied back to keep it on the stump (fig. 19).

Raised intermediate support spars are used when a support is needed and suitable trees are not available. Raising an intermediate support spar requires a portable winch.

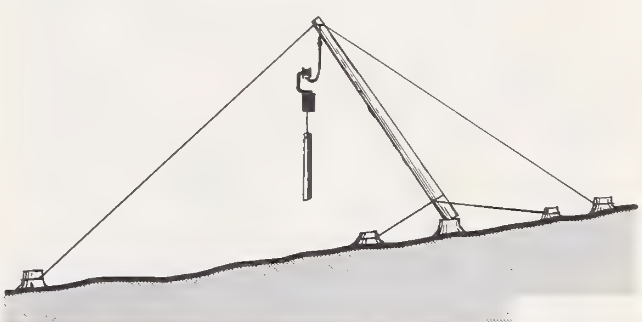


Figure 19

Cross-section view of a leaned intermediate support spar showing carriage, guy lines, and spar.

## Cross Support Skylines

The cross support skyline is a cable tensioned across a cutting unit to high points on both sides of the unit (fig. 20). It supports the main skyline in the same manner as an intermediate support spar. This type is used when terrain features make the use of support spars impractical.

Drainage heads with fan-shaped units are best suited to use of a cross support skyline.

The major portion of the rigging for a unit can be accomplished before actual logging begins. Moving the skyline or road changing is simplified when cross support skylines are used.

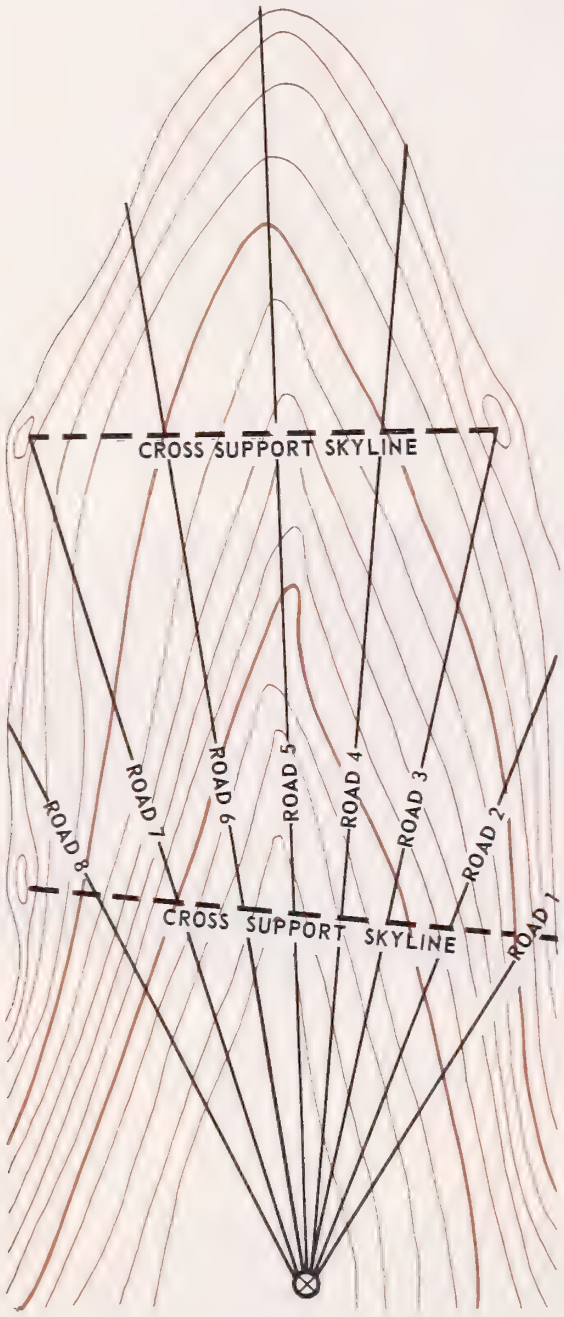



Figure 20

Drainage head with fan-shaped layout and cross support skylines.

## Special Rigging Situations

GROUND RIGGING IN PLACE OF HEAD OR TAIL SPARS.—When terrain allows use of tail-hold anchors to replace spars, erecting the skyline can be accomplished with a minimum of effort (fig. 21).

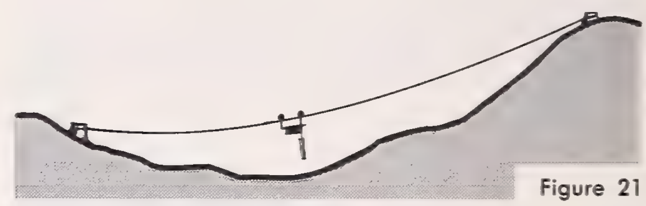


Figure 21

Single-span skyline rigged with tail-hold anchors.

OPERATING LINE ROLLERS.—Line rollers may be placed under the skyline on terrain that would be abrasive to the snubbing line. The roller is a sheave mounted in a steel frame which holds the line clear of the ground (fig. 22).

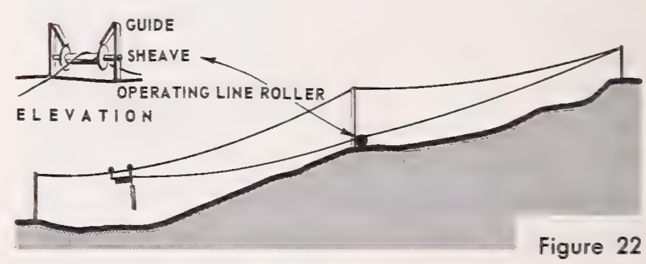



Figure 22

Operating line roller placed to reduce abrasion of the snubbing line.

SKYLINE JACKS.—The skyline jack is a J-shaped device, suspended from an intermediate support spar or cross support skyline, and allows an open-sided carriage to travel along the skyline (fig. 23).

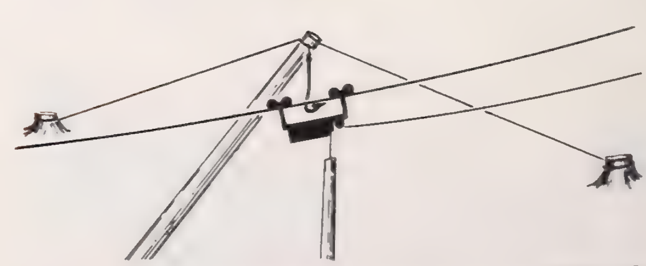


Figure 23

Longitudinal cross section of open-side carriage passing a skyline jack.

TAIL-HOLD ANCHORS.—The anchor for a skyline must resist the maximum load supported by the skyline. Anchors at the bottom of a unit are generally easier to rig than at the top because of less tension and because the stumps are generally larger. If a large stump is not available, a series of small stumps may be rigged to make a suitable anchor (fig. 24). Anchoring at the top of a unit, where stumps are usually smaller and where tension is greatest, presents a more difficult rigging situation.

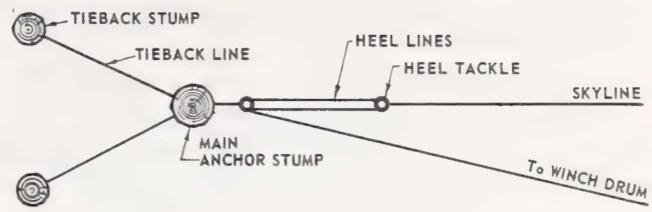



Figure 24.—Plan view of rigging a main anchor stump with tieback stumps.

Usually, a series of stumps is required to make a satisfactory anchor at the upper end of a skyline. Figure 25 shows a method for rigging an anchor with 8 stumps and tiebacks to an additional 16 stumps. Placing single-part blocks back to back equalizes the strain on each stump.

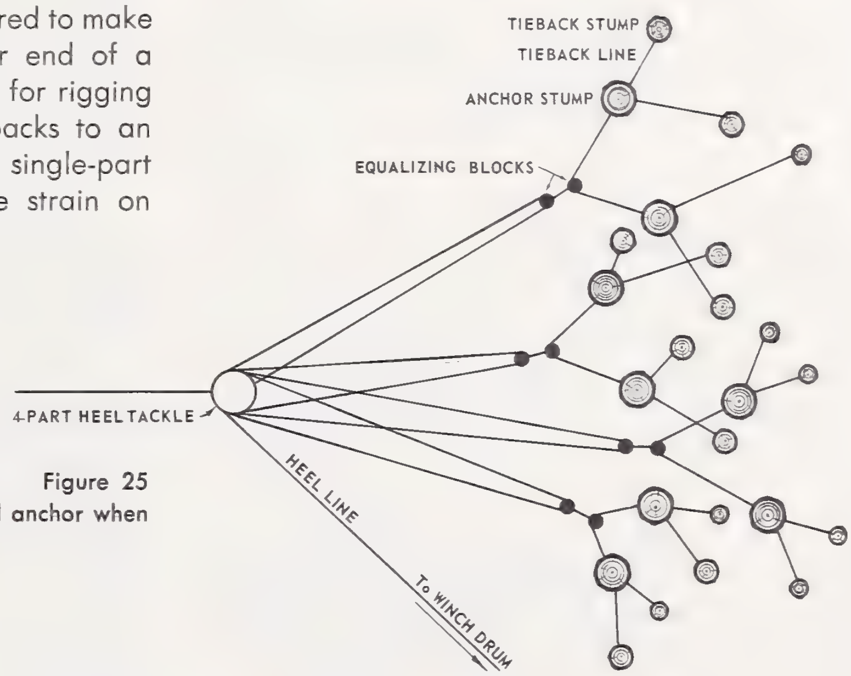
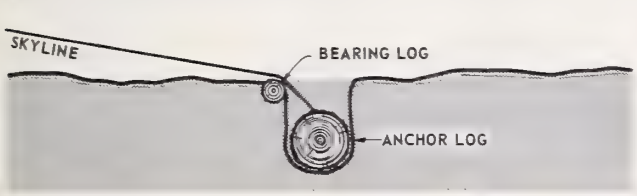



Figure 25
Plan view of a method of rigging a tail-hold anchor when small anchor stumps are used.

"DEADMAN" ANCHORS.—Where suitable stumps are not available, a "deadman" may be used as a tail-hold anchor. Various methods for constructing deadmen can be used; however, a buried log is the most practical (fig. 26).

Figure 26.—Cross-section view of a "deadman" anchor.




ALINEMENT OF SKYLINES.—Skyline supports must be alined between the head and tail spars (fig. 27). Lateral deflection in the skyline, caused by the support jacks being out of alinement, increases wear on the skyline and reduces the speed of the carriage passing an intermediate support. If a skyline jack is severely out of alinement, it could cause derailment of the carriage or damage the safety device which keeps the carriage on the skyline.

Figure 27.—Aerial perspective of a misalined multispan skyline.

## Skyline Deflection and Tension

Deflection and tension in a suspended cable can be calculated by using formulas taken from wire rope and engineering handbooks. These calculations are routine for single spans but very complex for multispan skylines. No attempt will be made to cover this subject in this paper.

To insure proper working loads, some operators have placed load cells in the skyline near the upper end so that tension can be accurately measured. However, there is no question that efficient design of a skyline logging system requires the determination of tension and de-deflection of the loaded skyline.

## Field Engineering

Prior to starting actual field work, the designer of the operation should make a reconnaissance of the cutting-unit perimeter, flagging the line to be run, marking suitable head and tail spars, and marking suitable landing locations at the bottom of the unit.

The next step is to run a closed traverse around the unit, including the head and tail spars and suitable tail-hold anchors. This traverse will give horizontal and vertical control of the unit. The traverse can be run as a meander line, avoiding undue delay by offsetting around obstacles and brush.

The initial traverse will give angular control, as well as vertical and horizontal distance, that is necessary when the skyline road profiles are traversed.

The initial traverse can be plotted by use of bearings and distances or latitudes and departures. The bearing of each skyline road then can be calculated or measured, depending on the accuracy desired. Traverse of a skyline profile without the perimeter survey may be a waste of time if the bearing of the line between the head and tail tree is not accurate.

A two-man crew can accomplish field engineering with a staff compass, 200-foot engineer's chain, percent Abney, and slope correction tables.

TRAVERSE OF PROFILE LINES.—Each skyline road can be traversed with the bearing obtained from the plot of the initial survey. Suitable support trees should be tied to the traverse and their d.b.h. and height should be recorded.

SIDE SLOPE NOTES.—Side slope notes recorded at each station or setup can be used to paper locate the profile ("L" line) if the traverse line misses the intended tail tree by 50 feet or less. Figure 28 illustrates the note taking for this method of traverse. These notes will be found invaluable if the profile line must be moved a short distance right or left to take advantage of more desirable terrain, taller intermediate support trees, a more suitable tail tree, or a stronger tail hold.

NOTE TAKING, STAFF-COMPASS METHOD

| Station | Horizontal distance | Slope distance | Percent | Bearing | Difference in elevation | Elevation | Side Slope L | Side Slope R | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | (Feet) | (Feet) | | | | (Feet) | | | |
| 0 + 00 | | | | | | 1,500 | 0/50 | 0/50 | Center of landing |
| | 124.5 | 130 | +30 | N10W | +37.3 | | | | |
| 1 + 24.5 | | | | | | 1,537.3 | -50%/50 | +50%/50 | |
| | 139.3 | 150 | +40 | N10W | +55.7 | | | | |
| 2 + 63.8 | | | | | | 1,593.0 | -40%/50 | +55%/50 | |
| | 191.6 | 200 | -30 | N10W | -57.5 | | | | |
| 4 + 55.4 | | | | | | 1,535.5 | -30% 40 | +40% 50 | Support tree 36' left D.b.h. 36" - 110' |

Figure 28.—Method of note taking for a skyline profile traverse.

The technique for making an L profile line from the traverse notes is similar to the design technique used on a forest access road. Accurate side slope notes can be the difference between an accurate L line made in the office or the rerunning of a profile in the field.

## Developing a Harvest Plan for a Large Drainage

The following illustrates the use of a topographic map in making a harvest plan for a large drainage area to be logged by a gravity skyline system. In this design, the premise is that low-standard administrative roads would be constructed to the top of ridge lines separating major drainages (fig. 29).

A cutting pattern was developed to give an orderly harvest with systematic development of the main haul and administrative road system (table 1). Actual skyline logging of 4,071 acres, with an average volume per acre of 65,000 board feet, would take an estimated 9 years to complete, using six machines and crews. Details on the road systems are as follows:

| Road number | Construction standard | Length |
|---|---|---|
| 2,000 | SH14 | 4.37 miles |
| 2,020 | SL12 | 1.00 mile |
| 2,020 | SL10 | 5.62 miles |
| 2,022 | SL10 | 1.40 miles |
| 2,024 | SL10 | 1.40 miles |
| 2,060 | SL10 | 2.40 miles |
| 2,010 | SL10 | 3.62 miles |
| 2,030 | SL10 | 3.15 miles |
| Total | | 22.96 miles |

The data indicate that 5.37 miles of main haul road must be constructed to transport the logs to the lower edge of the harvest area. Administrative roads to the ridgetops total 17.59 miles. Charging the total administrative road cost to this area would be unrealistic, because these roads not only serve the skyline drainage but adjacent areas as well, an additional half of the skyline area would be served by this road system, and road density would be 15.19 miles of road divided by 9.54 square miles, or 1.59 miles of road per square mile. Road 2060 is considered an internal road in the skyline harvest area.

Total road construction cost would be less than that for high-lead logging, because only 5.37 total miles would be of a standard required for log hauling. The reduction in hauling costs, road maintenance, and added construction, when compared with high-lead yarding should also be considered. Silen and Gratkowski[4] found an average road density of 5.19 miles per square mile in the staggered-setting system of high-lead yarding. When average road density is compared, the skyline system reduces the amount of road needed by 5.19 minus 1.59, or 3.60 miles per square mile. The saving is even greater if only the high-standard roads are considered; this saving amounts to 5.19 minus 0.56, or 4.63 miles per square mile.

One should remember that, after a drainage has been committed to skyline harvest, it will be difficult, and in some cases economically impossible, to revert to conventional high-lead yarding because the remaining volume will not support road development costs.

[4] Silen, Roy R., and Gratkowski, H. J. An estimate of the amount of road in the staggered-setting system of clearcutting. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 92, 4 pp. 1953.

Table 1.—Data relative to the hypothetical cutting units of figure 29.

| Unit | Number of skyline roads | Average external distance | Factor | Average estimated swing | Acres | Sequence of cut | Acres per road |
|---|---|---|---|---|---|---|---|
| | | Feet | | Feet | | | |
| 1 | 10 | 3,208 | 0.667 | 2,268 | 121 | 1 | 12.1 |
| 2 | 9 | 1,663 | ([1]) | 487 | 67 | 5 | 7.4 |
| 3 | 3 | 1,254 | .500 | 627 | 31 | 11 | 10.3 |
| 4 | 4 | 1,452 | .500 | 726 | 55 | 8 | 13.8 |
| 5 | 4 | 1,504 | .500 | 752 | 47 | 17 | 11.7 |
| 6 | 3 | 1,584 | .500 | 792 | 44 | 20 | 14.7 |
| 7 | 4 | 1,940 | .500 | 970 | 52 | 23 | 13.0 |
| 8 | 20 | 2,639 | .667 | 1,866 | 272 | 26 | 13.6 |
| 9 | 4 | 1,769 | ([1]) | 518 | 41 | 29 | 10.2 |
| 10 | 4 | 2,072 | .500 | 1,036 | 60 | 32 | 15.0 |
| 11 | 4 | 2,217 | .500 | 1,118 | 59 | 34 | 14.8 |
| 12 | 0 | -- | -- | -- | 48 | 3 | -- |
| 13 | 4 | 1,914 | ([1]) | 561 | 55 | 6 | 13.8 |
| 14 | 3 | 4,646 | .500 | 2,323 | 136 | 13 | 45.3 |
| 15 | 3 | 5,755 | .500 | 2,878 | 166 | 15 | 55.3 |
| 16 | 3 | 6,864 | .500 | 3,432 | 194 | 19 | 64.7 |
| 17 | 3 | 5,874 | .667 | 4,153 | 119 | 24 | 39.6 |
| 18 | 2 | 5,003 | .500 | 2,501 | 80 | 27 | 40.0 |
| 19 | 4 | 3,696 | ([1]) | 1,083 | 90 | 30 | 22.5 |
| 20 | 3 | 5,267 | .500 | 2,634 | 145 | 33 | 48.3 |
| 21 | 4 | 5,029 | .500 | 2,515 | 147 | 2 | 36.8 |
| 22 | 3 | 4,343 | .500 | 2,672 | 140 | 7 | 46.7 |
| 23 | 4 | 3,128 | .500 | 1,564 | 108 | 10 | 27.0 |
| 24 | 5 | 2,851 | .667 | 2,016 | 72 | 14 | 14.4 |
| 25 | 2 | 2,732 | .500 | 1,366 | 55 | 21 | 27.5 |
| 26 | 3 | 2,389 | .500 | 1,195 | 45 | 31 | 15.0 |
| 27 | 4 | 2,653 | .500 | 1,326 | 63 | 4 | 15.8 |
| 28 | 5 | 4,065 | .500 | 2,033 | 140 | 28 | 28.0 |
| 29 | 4 | 4,633 | ([1]) | 1,357 | 162 | 9 | 40.5 |
| 30 | 9 | 5,742 | .667 | 4,060 | 296 | 16 | 32.9 |
| 31 | 5 | 5,306 | .500 | 2,653 | 288 | 25 | 57.6 |
| 32 | 7 | 3,168 | .667 | 2,240 | 143 | 22 | 20.4 |
| 33 | 5 | 2,086 | .500 | 1,043 | 88 | 18 | 17.6 |
| 34 | 5 | 2,297 | .500 | 1,148 | 113 | 12 | 22.6 |
| 35 | 0 | -- | -- | -- | 178 | -- | -- |
| 36 | 0 | -- | -- | -- | 41 | -- | -- |
| 37 | 0 | -- | -- | -- | 110 | -- | -- |
| | | | | | 4,071 | | |

[1] Factors for these units have not yet been determined.


Figure 29
Topographic map layout showing the various cutting-unit designs and related terrain.

# Economic Analysis

Two important aspects of new logging systems can be examined by an economic analysis: what phases of the operation are costly yet subject to improvement and what are the total costs under given situations. In this study the economic analysis consisted of a time study of the various phases of the skyline yarding cycle, regression analysis of the major factors affecting yarding time, calculation of hourly labor and equipment costs, and conversion of hourly costs to costs per thousand board feet. These are presented here in detail and an example of cost estimation is included.

## Time Study

The time study on the experimental area covered 327 turns, spread over a 6-month period. Timing was generally conducted in units of whole days or half days so as to obtain an unbiased sample of turn and delay times. Breakdown time was secured from company records; the method of recordkeeping was designed especially for this study.

The six time phases of a logging cycle were timed separately by the snapback technique, recording time to the nearest tenth of a minute. Time for each individual phase was recorded separately. The method of timing is described as follows:

Phase $T_1$. Time required to move the unloaded carriage from the landing to point of loading. Time started with the signal to start the carriage up the skyline and ended when the carriage reached the point of loading.

Phase $T_2$. Time required by the rigging crew to pull the skidding line laterally from the carriage to the turn of logs. Time started when the carriage reached the point of loading and ended when the skidding line was pulled laterally to the turn of logs.

Phase $T_3$. Time required to hook a turn of logs to the carriage skidding line. Time started when the skidding line reached the turn of logs and ended when the rigging crew was in the clear and the signal was given to skid the turn laterally to the carriage.

Phase $T_4$. Time required to skid turn of logs laterally to the carriage. Time started when the signal was given to skid the turn laterally to the carriage and ended when the turn was under the carriage.

Phase $T_5$. Time required to move the loaded carriage down the skyline from the point of loading to the landing. Time started with the movement of the carriage and stopped when the carriage reached the landing.

Phase $T_6$. Time required to unhook a turn of logs. Time started when the carriage reached the landing and ended when the logs were unhooked and the carriage was ready to begin a new cycle.

## Analysis of Factors Affecting Time and Cost

Major variables, considered as affecting the various phases of yarding time, were identified and recorded as follows:

- $D_1$ Distance in feet that carriage travels along skyline, measured from skyline profiles using straight-line chords for deflected skyline.
- $D_2$ Lateral slope distance in feet, measured perpendicularly from the skyline.
- $S_1$ Slope of skyline in percent, calculated with horizontal and vertical distances taken from profile, coded in tens in formula, i.e., 80 percent = 8.
- $S_2$ Lateral slope in percent at right angles to the skyline, coded in tens in formula, i.e., 80 percent = 8.
- $S_3$ Ground slope in percent directly under the skyline, coded in tens in formula, i.e., 80 percent = 8.
- I Number of intermediate supports.

C Number of men in rigged crew that pulls skidding line laterally and hooks chokers.

N Number of logs in each turn.

B Slash index measured as (1) light, (2) medium, or (3) heavy.

V Turn volume in board feet, gross scale, Scribner Decimal C. Coded in formula, 1,000 board feet = 100.

Regression equations were calculated for each of the six phases of the yarding cycle based on tests for significance using the following combinations of independent variables:

$T_1$, carriage haulback time as related to $S_1$, I, and D.

$T_2$, time to pull out skidding line laterally from skyline as related to $D_2$, $S_2$, B, C, $D_2^2$, $S_2^2$, and $D_2S_2$.[5]

$T_3$, hooking time as related to $S_2$, $S_3$, $S_3^2$, B, N, and V.

$T_4$, lateral yarding time as related to $D_2$, $S_2$, B, N, V, $D_2^2$, $D_2S_2$, and $S_2^2$.

$T_5$, time for downhill movement of the loaded carriage as related to I, $D_1$, $S_1$, N, V, $D_1^2$, and $ID_1$.

$T_6$, unhooking time as related to N and V.

Only those independent variables were retained whose correlation was statistically significant, measured at the 5-percent confidence level. The surviving equations were as follows, with time measured in minutes ($T_1$, $T_5$, $T_6$), and in tenths of minutes ($T_2$, $T_3$, $T_4$):

| | Coefficient of multiple correlation |
|---|---|
| Carriage haulback time: | |
| $T_1 = -0.07053 + 0.00819S_1 + 0.10114I + 0.00099D_1$ | 0.9910 |
| Time to pull skidding line laterally from skyline: | |
| $\text{Log } T_2 = 0.89995 + 0.0020715D_2$ | 0.6694 |
| Choker-set time: | |
| $\text{Log } T_3 = 0.6147 + 0.09082N + 0.03169S_2$ | 0.5546 |
| Lateral yarding time: | |
| $T_4 = 3.7056 + 0.00001384D_2V + 0.03839D_2 + 0.004127V$ | 0.6604 |
| Time for downhill movement of the loaded carriage: | |
| $T_5 = 1.26906 + 0.70866I + 0.000287D_1$ | 0.9419 |
| Unhooking time: | |
| $T_6 = 1.37699 + 0.16345N$ | 0.5822 |

These equations are shown graphically in figures 30 to 35.

Timing of $T_1$ and $T_5$ was done over fixed distances rather than varied distances ranging from zero. The equations were not curvilinear, nor will the curves originate at zero. A total or constant-speed time was developed rather than a curve for acceleration and deceleration of the carriage. Estimated time and distances for these functions are drawn as dashed lines on figures 30 and 34.

The total time in figure 31 is the average total time to lower the skidding line from the carriage and for the rigging crew to untangle chokers before pulling the skidding line laterally to the turn of logs.

Data for three- and four-man rigging crews were recorded and analyzed. The analysis showed, and was verified by referring to the field data, that the four-man crew, working on terrain comparable to that of the three-man crew, consistently required more time. The reason for this time difference could not be identified. Therefore, only the results from the three-man crew will be presented in this paper. Hooking, in comparison of the three- and four-man crews, resulted in the same relationship as in phase $T_2$. Comparison of crew size for hooking time will also be omitted. Time for hooking with and without present chokers was also compared in this study and, as was expected, preset chokers greatly reduced hooking time. The equation for a three-man crew using preset chokers was selected for presentation in this paper (fig. 32).

Figure 33 is a graphic presentation of phase $T_4$, the lateral skidding of logs to the carriage. Slope $S_2$ did not survive as a significant variable in the analysis which led to this presentation.

[5] Logarithmic transformations were made for $T_2$ and $T_3$.

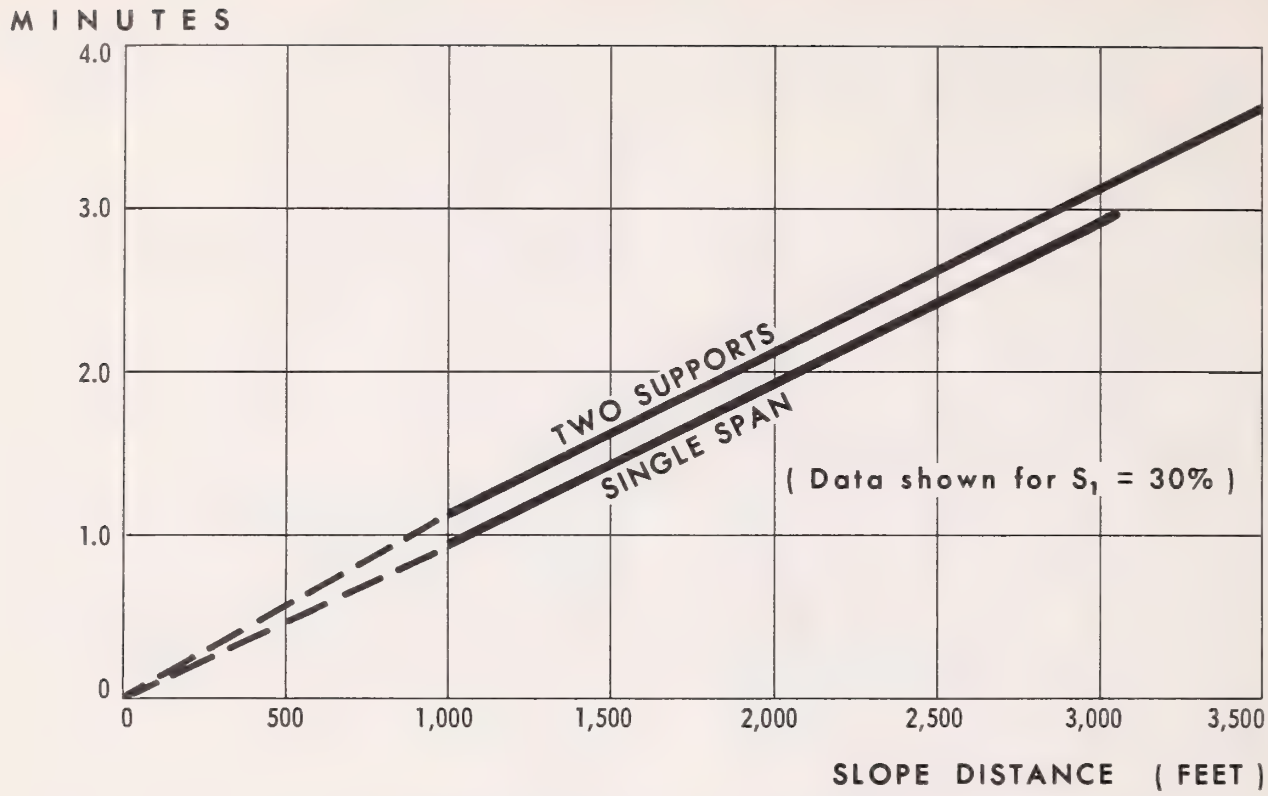



Figure 30.—Carriage haulback time. $T_1 = -0.07053 + 0.00819S_1 + 0.10114I + 0.00099D_1$.

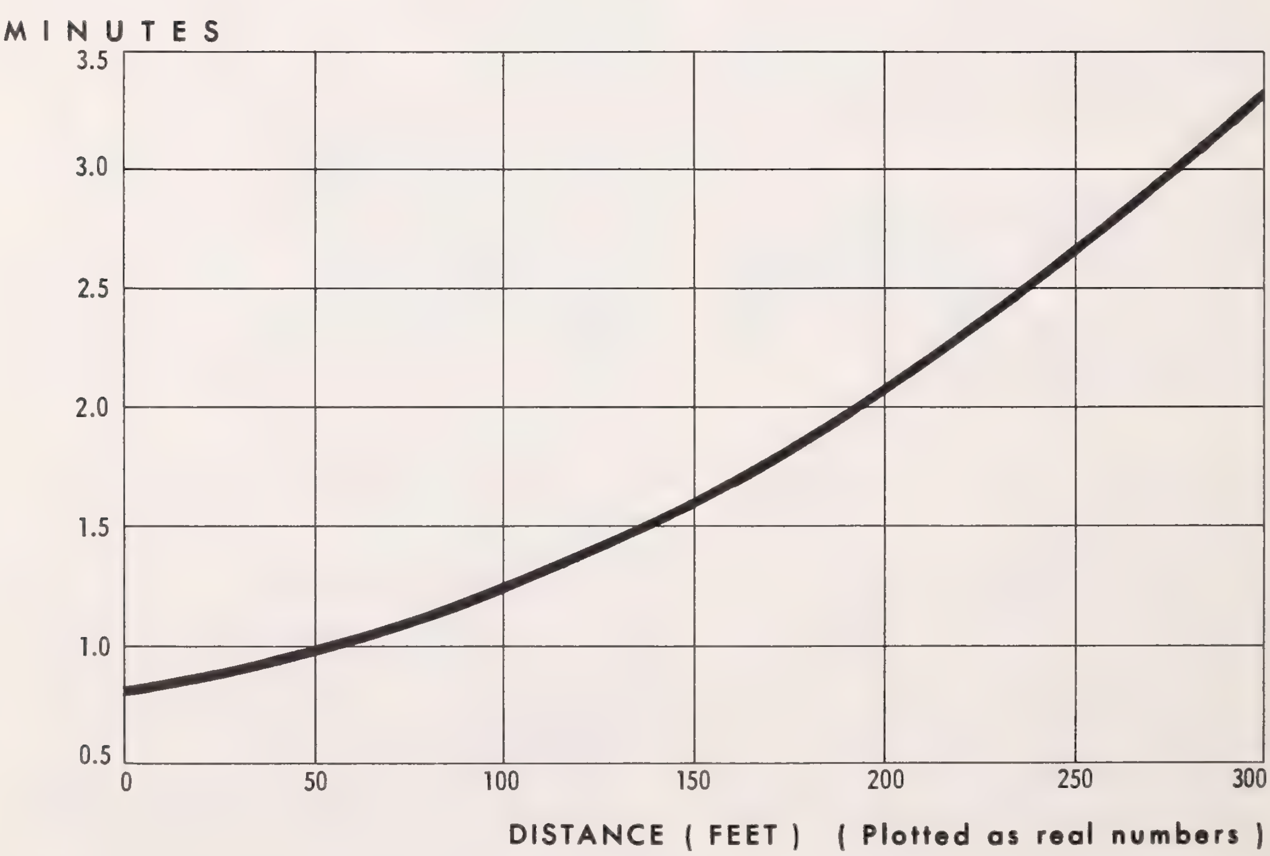



Figure 31.—Time to pull skidding line laterally from skyline (3-man crew). Log $T_2$ (in tenths of minute) = 0.89995 + $0.002071D_2$.

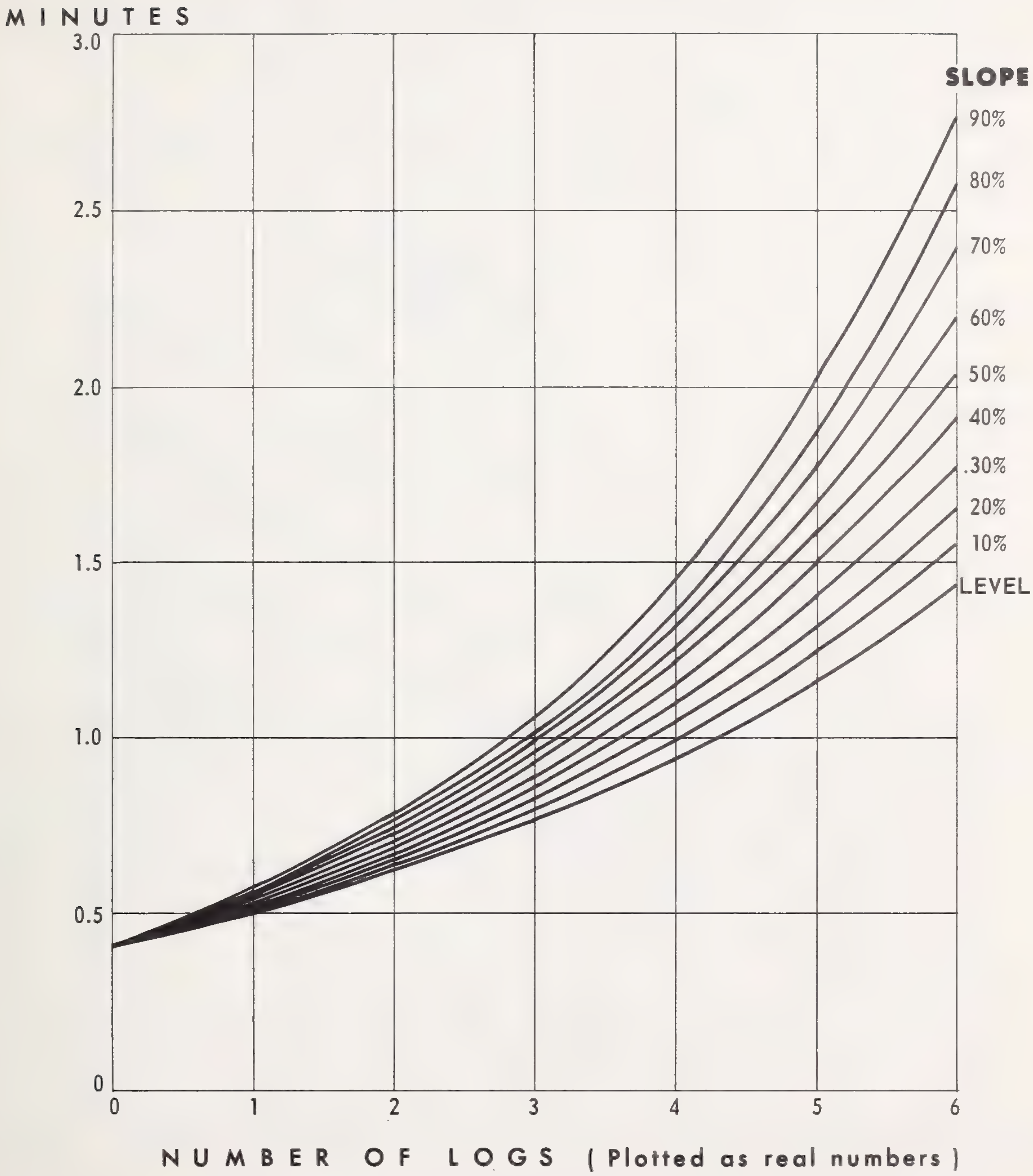



Figure 32.—Hooking time (3-man rigging crew, preset chokers). Log $T_3$ (in tenths of minute) $= 0.6147 + 0.09082N + 0.03169S_2$.

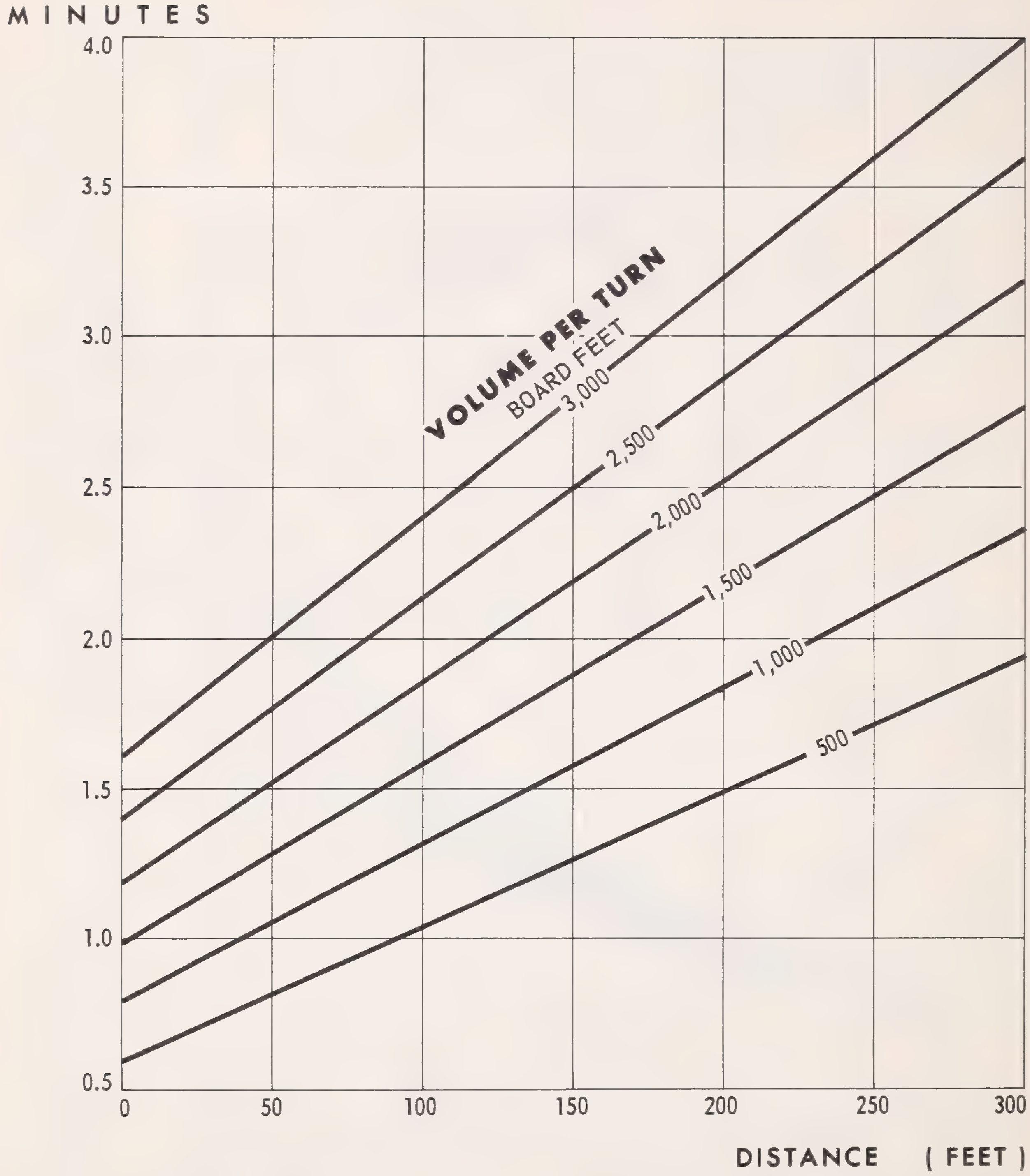



Figure 33.—Lateral yarding time. $T_4$ (in tenths of minute) $= 3.7056 + 0.00001384D_2V + 0.03839D_2 + 0.004127V$.

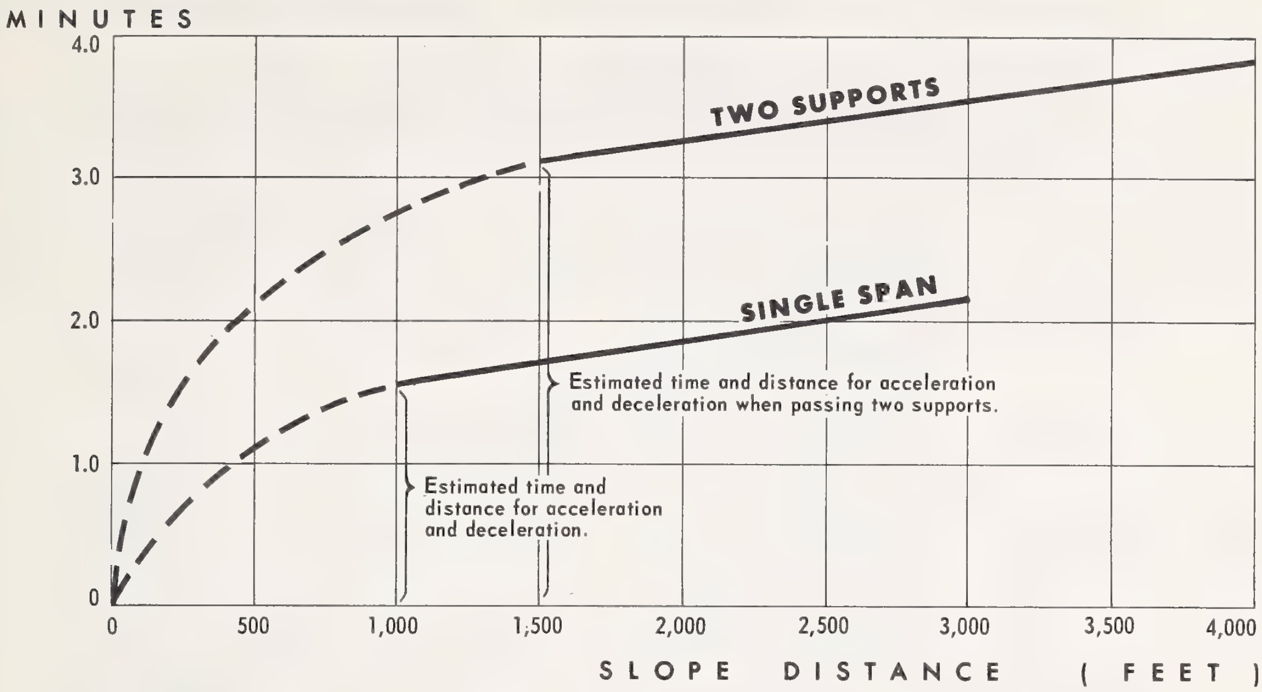



Figure 34.—Time for downhill movement of the loaded carriage. $T_5 = 1.26906 + 0.70866I + 0.000287D_1$.

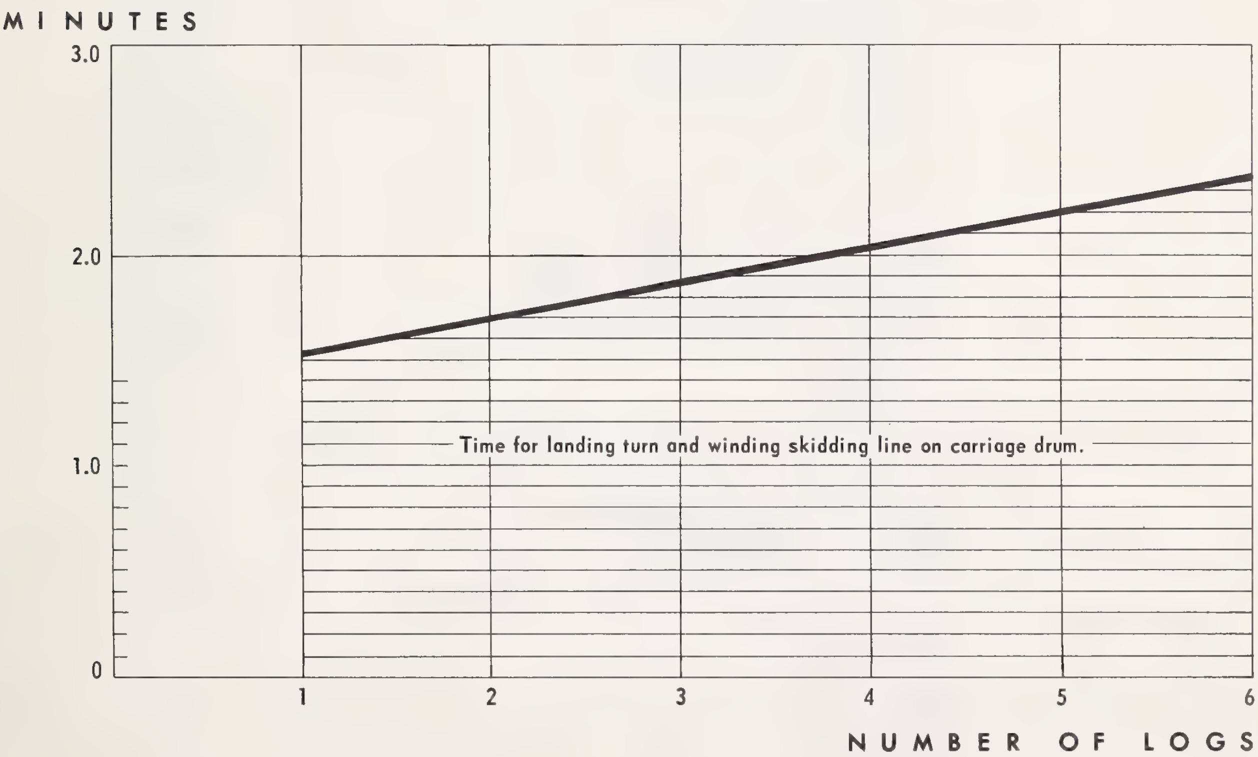



Figure 35.—Unhooking time. $T_6 = 1.37699 + 0.16345N$.

Table 2.—Quantity and cost of equipment for a radio-controlled skyline system

| Quantity | Description | Cost |
|---|---|---|
| 1 | Snubbing machine BX185 with hydrotarder[1] | $47,380.00 |
| 1 | RCC-20 Skycar[1] | 23,670.00 |
| 1 | Radio equipment[1] | 5,700.00 |
| | | 76,750.00 |
| | Rigging equipment:[2] | |
| 1 | High-lead block, 24 inches by 3 feet | 686.00 |
| 2 | Tree shoes, 48 inches by 4 inches | 1,116.00 |
| 1 | Multipart heel tackle, 18-inch | 1,140.00 |
| 1 | Skidder head hook, 1-inch | 74.25 |
| 1 | Skidder second hook, 1-inch | 77.00 |
| 4 | Moving blocks, 10 inches by 1-1/2 inches | 167.00 |
| 4 | Rigger's block, 4 inches by 1-1/4 inches | 140.00 |
| 26 | Tree plates, 7/8 inch by 3 inches by 3 feet | 702.00 |
| 1 | Claw bar, 3-foot | 27.00 |
| 1 | Rigger's pass chain, 3/8 inch by 7-1/2 feet | 28.00 |
| 1 | Rigger maul | 21.00 |
| 1 | Splicing needle, 12-inch | 7.50 |
| 2 | Splicing needles, 18-inch | 16.80 |
| 1 | Splicing needle, 20-inch | 10.00 |
| 1 | Rigger's belt with rope and chain[3] | 47.90 |
| 1 | Set climbing spurs[3] | 29.50 |
| 12 | Wire rope clips, 2-inch | 306.00 |
| 34 | Guy line sleeves, 1-1/4 inch | 459.00 |
| 4 | Winch line clevises, 1-3/8-inch | 86.40 |
| 4 | Tree straps,[3] 2 inches by 18 feet | 759.36 |
| 2 | Tree straps,[3] 2 inches by 16 feet | 367.96 |
| 2 | Tree straps,[3] 2 inches by 12 feet | 344.52 |
| 16 | Guy lines, 3/4 inch by 200 feet[4] | 1,216.00 |
| 16 | Guy lines, 1 inch by 200 feet[4] | 1,856.00 |
| 300 lbs. | Railroad spikes | 36.00 |
| | Miscellaneous tools[5] | 500.00 |
| 1 | Portable guy line tightener[6] | 38.50 |
| 1 | Operating line roller[5] | 600.00 |
| 1 | Chain saw[3] | 297.35 |
| | | 11,157.04 |
| | Wire Rope:[4] | |
| 1 | Skyline, 2 inches by 5,000 feet | 10,650.00 |
| 1 | Snubbing line, 1 inch by 5,000 feet | 2,900.00 |
| 1 | Straw line, 3/8 inch by 6,000 feet | 960.00 |
| 2 | Carriage load lines, 3/4 inch by 500 feet | 380.00 |
| 25 | Chokers, 5/8 inch by 20 feet[2]/[5] | 217.00 |
| | | 15,107.00 |
| | Fire equipment:[6] | |
| 4 | Water barrels[5] | 20.00 |
| 6 | Shovels | 24.00 |
| 6 | Fire axes | 68.28 |
| 4 | Backpack pumps | 96.00 |
| | Fire hose, 1 inch by 1,000 feet | 500.00 |
| 1 | 300 gal. portable pump[5] | 1,500.00 |
| 1 | 500 gal. firetruck and pump[5] | 2,500.00 |
| | | 4,708.28 |
| | Engineering supplies:[6] | |
| 1 | Staff compass | 60.50 |
| 1 | Jacob's staff | 6.00 |
| 1 | 200-foot engineer's chain | 45.40 |
| 1 | Machete | 2.95 |
| 2 | Abney levels | 72.00 |
| | Miscellaneous engineering supplies | 50.00 |
| | | 236.85 |
| | Total | $107,959.17 |

[1] Skagit Steel & Iron Works.
[2] Young Iron Work catalog.
[3] Local retailer.
[4] Broderick and Bascom catalog.
[5] Estimate.
[6] Retail catalog.

## Calculation of Hourly Costs

LABOR COSTS.—The five-man crew includes engineer (snubbing-machine operator), rigging slinger (man in charge of rigging crew), two choker setters, and chaser (unhooker at landing). Wages, plus payroll overhead of approximately 22 percent for social security, vacation pay, accident insurance, and related charges, were estimated at $150 per day, or $18.75 per hour.

EQUIPMENT COSTS.—Costs of equipment were calculated as shown in tables 2, 3, and 4. Average investment was calculated as one-half the sum of original cost and salvage value. Basis of calculation was 215 operating days per year. Interest was calculated at 6 percent, and was considered an economic cost, whether or not interest payments are made, because if internal funds are used to purchase equipment, they cannot earn an approximately equivalent rate elsewhere. Taxes were calculated at 2 percent of average investment. Insurance was calculated at $1.25 per $100 for 80 percent of average investment. Lubrication cost of machines was calculated at 15 percent of fuel cost. Repairs and maintenance were calculated at 50 percent of depreciation for the snubbing machine, or 90 percent for Skycar and radio equipment.

EFFECT OF DELAYS AND BREAKDOWN TIME.—A record was kept of total operating and nonoperating hours for the period the skyline equipment was on the study setting. There were 1,357 operating hours and 215 nonoperating hours, for a total of 1,572 hours. Operating hours were therefore 86.3 percent of total time available for productive yarding.

Table 3.—Derivation of average investment and fuel cost and consumption for yarding equipment

| Item | Useful life | Original cost | Salvage value | Average investment | Fuel cost, per gallon | Fuel consumption, per hour |
|---|---|---|---|---|---|---|
| | Years | Dollars | | | | Gallons |
| Snubbing machine | 7 | 47,380 | 9,476 | 28,428 | 0.165 | 8 |
| Skycar carriage | 7 | 23,670 | 2,367 | 13,019 | 0.195 | 2 |
| Radio equipment | 7 | 5,700 | 0 | 2,850 | -- | -- |
| Rigging equipment | 3 | 11,157 | 1,116 | 6,136 | -- | -- |
| Wire rope | 3 | 14,510 | 1,451 | 7,981 | -- | -- |
| Fire equipment | 5 | 4,708 | 471 | 2,589 | -- | -- |
| Engineering equipment | 5 | 474 | -- | -- | -- | -- |

Table 4.—Calculation of hourly costs for yarding equipment (In dollars)

| Item | Costs per day | | | | | | | | | Total cost, per hour |
|---|---|---|---|---|---|---|---|---|---|---|
| | Depreciation | Interest | Taxes | Insurance | Fuel | Lubrication | Repairs and maintenance | Other | Total | |
| Snubbing machine | 25.19 | 7.93 | 2.64 | 1.32 | 10.56 | 1.58 | 12.60 | -- | 61.82 | 7.73 |
| Skycar carriage | 14.15 | 3.63 | 1.21 | .61 | 2.64 | .40 | 12.74 | -- | 35.38 | 4.42 |
| Radio equipment | 3.79 | .80 | .27 | .13 | -- | -- | 3.41 | -- | 8.40 | 1.05 |
| Rigging equipment | 15.57 | 1.71 | .57 | -- | -- | -- | -- | -- | 17.85 | 2.23 |
| Wire rope | 20.25 | 2.23 | .74 | -- | -- | -- | -- | [1]2.78 | 26.00 | 3.25 |
| Fire equipment | 3.94 | .72 | .24 | -- | -- | -- | -- | -- | 4.90 | .61 |
| Engineering equipment | .22 | -- | -- | -- | -- | -- | -- | -- | .22 | .03 |
| Total | | | | | | | | | | 19.32 |

[1] Covers 25 chokers per year ($217) plus two skidding lines per year ($380).

## Direct Costs Per Thousand Board Feet

The regression equations for time were used to calculate times per turn. These times, multiplied by labor and equipment costs per minute, will give direct cost per turn; such costs, divided by turn volume, give direct cost per thousand board feet (fig. 36).

These direct costs show only the extra cost of yarding an extra turn; they do not include development costs, rigging costs, and costs of felling and bucking, crew transportation, supervision, or general overhead.

Note that the calculated direct yarding costs can vary from over $25 per thousand board feet for a turn volume of 250 board feet to about $3 per thousand board feet for a turn volume of 2,500 board feet for a given span distance. This illustrates the importance of turn volume as a cost-determining factor.

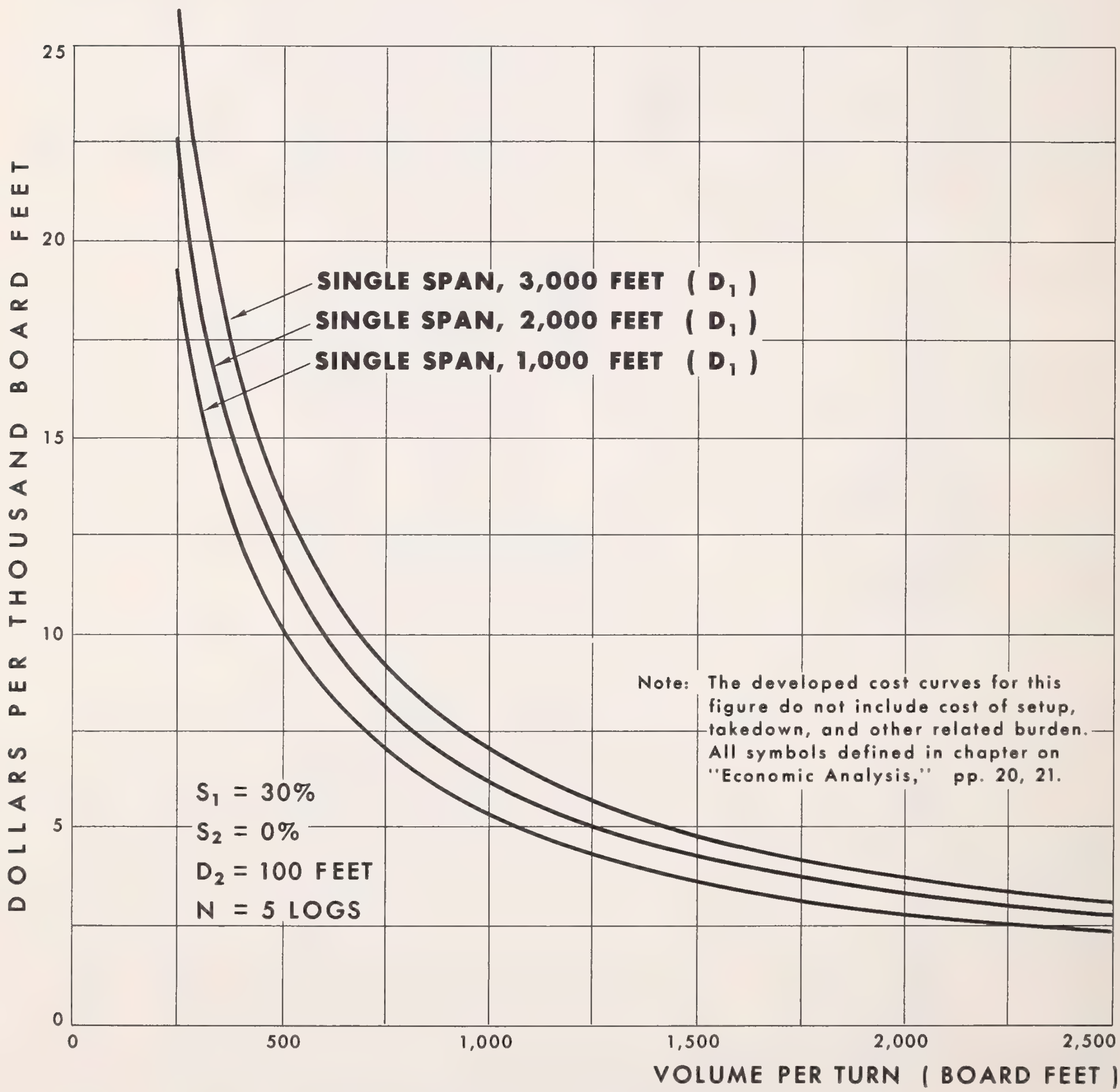



Figure 36.—Direct yarding cost per thousand board feet as related to carriage loading.

# Application of Results

The foregoing information on layout, design, and cost estimating can be used for planning possible skyline operations over a wide range of operating conditions. Calculation of average times for the six individual phases of the yarding cycle will permit estimation of production rates and average yarding costs. Timber sale administrators and logging managers will find that such planning is not difficult and that it leads to a clearer understanding of the operating requirements for efficient use of skyline methods and equipment.

## A Practical Example

A practical example is developed below, using data obtained in this study. In developing this example, the following conditions are assumed:

1. Rectangular setting, 800 by 2,500 feet horizontal distance
2. Single-span skyline
3. Gradient of skyline, 30 percent
4. Lateral slope, zero percent under the skyline
5. Spar support, needed at top and bottom.
6. Volume per acre, 45,000 board feet, gross scale
7. Scaling defect, 13 percent
8. Average log, 300 board feet, gross scale
9. Average load, five logs, or 1,500 board feet
10. Operating crew, five men
11. Use of preset chokers
12. Effective work hour, 50 minutes
13. Average lateral yarding distance, 100 feet
14. Average skyline distance, 1,300 feet (obtained graphically)

Estimated times are as follows:

| | |
|---|---|
| Average $T_1$ = | 1.25 minutes |
| Average $T_2$ = | 1.22 minutes |
| Average $T_3$ = | 1.16 minutes |
| Average $T_4$ = | 1.58 minutes |
| Average $T_5$ = | 1.61 minutes |
| Average $T_6$ = | 2.20 minutes |
| Total | 9.02 minutes |

With an estimated 50-minute effective work hour, 9.02 minutes per turn will result in 5.54 turns per clock hour. Then, 5.54 turns per hour multiplied by 1,500 board feet per turn multiplied by 8 hours per day = 66,480 board feet per day, gross scale, and 66,480 multiplied by 0.87 = 57,838 board feet per day, net scale.[6]

## Yarding Costs

Estimated yarding costs are as follows:

| | | Average cost per thousand board feet, net scale |
|---|---|---|
| | | (Dollars) |
| Labor cost: $\frac{\$150 \text{ per day}}{57{,}838 \text{ board feet per day}}$ | | 2.59 |
| Rigging cost: | | |
| 4 spar trees at $1,000 per tree | $4,000 | |
| 4 tail holds at $500 each | 2,000 | |
| Move-in and miscellaneous rigging, 5 days, including labor and machine cost | 1,100 | |
| | $7,100 | |
| 45.91 acres x 45,000 board feet per acre x 0.87 = 1,797,000 board feet, net scale | | |
| $7,100 divided by 1,797 | | 3.95 |
| Machine cost: $\frac{\$19.32 \times 8 \text{ hours per day}}{57{,}838 \text{ board feet per day}}$ | | 2.67 |
| Total | | 9.21 |

## Discussion

A critical assumption in the above example is that turn volumes will average 1,500 board feet.

It was observed that unhooking, which accounts for 21 percent of the cycle time in the example, could be reduced by releasing the chokers from the butt-hooks and attaching a new set of empty chokers to be sent back with the empty carriage. The chokers could be unhooked while the logs are being moved from the landing area to the various sorting piles. Reducing cycle time by 1 minute in the example would increase production 7,203 board feet, net scale, per day.

[6] The figure 0.87 accounts for 13 percent scaling defect.

Use of average times, production rates, and costs provides a useful method of analysis. However, this does not eliminate the need for attention to the wide variation in times and costs for individual turns. Uneconomic individual turns and logs should be avoided wherever possible by close supervision following careful planning. The relatively high, fixed costs of this equipment make its minimum economic load much greater than for other yarding methods.

# Concluding Remarks

Skyline yarding systems offer an effective means of moving logs from steep slopes where special precautions must be taken to minimize soil disturbance. This is an important objective where there is relatively thin, unstable soil or terrain unfavorable for road construction.

For efficient performance, skyline yarding systems must be carefully planned, engineered, and supervised. This is necessary, not only from the standpoint of technical efficiency but also to keep down the relatively high costs of rigging, to avoid delays, and to achieve production rates that justify the relatively high, per-hour operating costs.

Multispan skylines tend to cost more than single-span skylines. This is reflected in increased cycle time, extended periods of nonproduction while rigging and dismantling the intermediate supports, and by the cost of this rigging. External distances up to 3,000 feet can be attained with a single span on certain topographic features; however, distances of not over 2,000 feet are more desirable. Introduction of the skyline-crane yarding system into a forest harvest plan should be done with a single-span setup until operators and logging crews become familiar with the system. Skyline profiles should be made and cutting-unit layout planned prior to moving equipment to the site.

During the course of this study, several possibilities were noted for reducing costs. These include use of preset chokers to reduce cycle time, changing gear ratios on the yarder to increase speed of the empty carriage up the skyline, improvement of the tote road to the top of cutting unit to permit use by 4-wheel drive or track-type personnel carriers, and development of a safe device to permit personnel to ride the carriage.

Carriage loading is a significant factor in attaining the designed production of the skyline system. Study of the various time elements will show that loading the carriage to designed capacity causes a slight reduction in number of turns per hour but results in a greatly increased hourly and daily volume production.

Although direct yarding costs for skyline yarding are generally greater than for conventional high-lead yarding, these are offset in part by the reductions in road costs, truck hauling distance, and log breakage. Therefore, a complete cost analysis is needed before a choice is made among alternative logging systems. This report provides information and procedures for such analysis of skyline logging.



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Binkley, Virgil W.

1965. Economics and design of a radio-controlled skyline yarding system. U. S. Forest Serv. Res. Paper PNW-25, 30 pp., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

This study presents an analysis of factors affecting time and costs of skyline logging in mature Sitka spruce and western hemlock on the Cascade Head Experimental Forest near Otis, Oreg. Stopwatch time studies were made to relate elements of cycle time to load volume, yarding distance, slope, crew size, and other factors. Engineering aspects of skyline yarding operations are also discussed.

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